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INTRODUCTION

THIS ISSUE concerns itself with research in the teaching of mathematics, including arithmetic, algebra, and geometry; the teaching of natural sciences, including astronomy, botany, chemistry, geology, physics, and zoology; and the teaching of such combinations of the natural sciences and of mathematics as are found in the curriculums of American public schools or in extracurriculum situations. General mathematics, biology, health, and physical science are included, but agriculture, home living, and geography are not.

Both the curriculum and the psychology of learning are reviewed as far as they pertain to mathematics and to natural sciences in any range of public-school activities, from the primary grades through the junior college. Thus the present issue becomes sequential to the issues of April 1937, dealing with "The Curriculum"; of December 1937, dealing with "Special Methods and Psychology of the Elementary School Subjects"; and of February 1938, dealing with "Psychology and Methods in the High School and College." Reports on research in extraschool education in mathematics and science and in the preparation of teachers of science and mathematics are natural extensions of the areas previously reviewed.

The bibliographies are selective rather than comprehensive, listing only a portion of the hundreds of investigations concerned with the teaching of science and mathematics made available during the period covered. Some research in other countries is included, but American research is considered for the most part.

Bringing together for the first time educational research from mathematics and science into a single summary was felt to create a need for a brief initial chapter examining critically the social and philosophical matrix from which research in education must stem. The remaining chapters are essentially reviews of research which include critical evaluations to a certain extent.

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CHAPTER I

Overview of the Period

SAMUEL RALPH POWERS and VIVIAN EDMISTON

National Association Reports

RESEARCH STUDIES have been both a stimulus of and a basis for the reports of national committees during the period reviewed here. The Commission on Secondary School Curriculum of the Progressive Education Association made the two reports, *Science in General Education* (20) and *Mathematics in General Education* (19). The report on the teaching of science to meet needs of adolescents in a democracy deals with student needs in four major areas: personal living, personal-social relationships, social-civic relationships, and economic relationships. It discusses science teaching in relation to reflective thinking and makes concrete suggestions about evaluating student growth in relation both to abilities which are "intangible" and to abilities which are easily measured. The report on the teaching of functional mathematics for general education purposes is similar to the science report.

Yearbooks of the National Council of Teachers of Mathematics have dealt with various aspects of mathematics teaching, namely: approximate computation (2), teaching high-school students to use logical proof in their everyday living (7), preparation of high-school mathematics teachers in the United States and in England and Wales (26), secondary-school mathematics (16), and arithmetic as a phase of general education (25). Each of these reports is mentioned in the present review at appropriate points.

Reports of the National Committee on Science Teaching of the American Council of Science Teachers of the National Education Association help to implement for the science teacher the recommendations of the Educational Policies Commission. *Science Teaching for Better Living* (17) presents the point of view that functional science has an important place in helping the individual to relate himself to the modern world and in furthering human betterment. *Redirecting Science Teaching in the Light of Personal-Social Needs* (6) stresses science teaching for meeting student needs. It gives an illustrative list of needs of students at various school levels. *The Education of the Science Teacher* (18) deals with the science teacher as a person and citizen functionally proficient in science and in teaching. *Effective Procedures and Materials for the Functional Teaching of Science* (14) makes concrete suggestions for improved science teaching that will prepare boys and girls for a democratic way of life in the world remade by science.

Research Bureau Reports

Some publications of the Bureau of Educational Research in Science (Teachers College, Columbia University) are already available, as is pointed out in Chapter VI. The Bureau has identified major problems of our society and has presented in a series of books for teachers (4, 8, 9, 12, 13, 22, 24) the interrelations of those problems with various areas of the sciences. Through the coming year there can be anticipated further publications: *Suggestions for Teaching*, which will report experiences of teachers who have taught in these problem areas; materials directly usable by high-school students; and further research studies on children who relate their science learning to social issues.

Comprehensive Studies

Science and mathematics have been handled as part of the educational matrix in each of the comprehensive studies in the period under review. In general the superiority of students having experimental activity programs over students having traditional programs is reported as inconclusive for science and mathematics and as actual for social understandings. In New York City ten selected experimental grade schools carrying on activity programs during the past six years were compared with ten matched schools offering regular programs. Morrison (15) reported that sixth-grade children in the activity program were much the same as those in the regular program in performance on arithmetic and science tests, and in "scientific outlook" and "interest in arithmetic." "Neither program has demonstrated as yet any superiority over the other in helping children to master that important area of arithmetic known as problem solving. . . . Neither does the analysis indicate that either program has any marked advantage over the other in . . . arithmetic computation." However, the study showed the attitude, "lack of subservience," and the ability to apply generalizations as more characteristic of children in the activity program than in the regular program. According to teachers, effects of the activity program included: "Children are more independent. . . . Enlarges children's world. . . . Children learn to defend own point of view. . . . Develops critical-thinking—scientific approach. . . . Children are more democratic. . . . Children seem to understand what they are doing and why. . . . Children learn to make decisions wisely."

At the secondary level, the Eight-Year Study (1, 5, 10, 20, 23), followed closely 1,475 graduates from "thirty schools" and a like number of matched students graduated from other high schools. Data obtained were interpreted as showing the desirability of revised bases for college entrance. Performance on intelligence tests, the pattern of student abilities, and evidence of achievement in an area of special interest during high school were found a better basis for recommending that a student be admitted to college than the usual requirements of a specified number and pattern of high-

school courses and a minimum average grade. In college, students from the "thirty schools" earned higher grade averages in both science and mathematics than did their matchees. Students of the experimental schools were judged superior in relation to certain abilities often implied in the term *scientific attitude*, namely: intellectual curiosity and drive; precise, systematic, and objective thinking; clear ideas concerning the meaning of education; resourcefulness in meeting new situations; ability to approach problems of adjustment effectively; active concern with what was going on in the world.

For the junior-college level, the Cooperative Study in General Education is in progress and deals with twenty programs of general education designed to meet student needs. For institutions concerned with the preparation of teachers, the report of the Commission on Teacher Education on its five-year study in thirty-four selected centers may be anticipated within one year.

Emphases of Reviews in This Issue

The present issue shows both the continuance of research along customary lines and the initiation of research compatible with current educational thought. Studies have included reports on the status of teaching personnel, course content, methods, and materials in use. At the elementary level, arithmetic readiness and grade placement received attention; and the interpretation of what constitutes elementary science has been broadened from nature study to study of all fields of science. At the secondary level, survey courses and functional courses in harmony with student needs and interests have been considered. In the preparation of teachers of science and mathematics, such studies as that of Burnett (3) have shown that teachers feel thwarted by their inability to deal with significant problems of our society and have need of more functional preparation in professionalized science.

Learning studies have dealt with the effectiveness of methods and devices associated both with traditional teaching and with newer practices. In elementary arithmetic, methods of teaching specific skills were studied, but so were methods of teaching children to solve problems and to use generalizations in doing so. In general, learning studies are becoming less concerned with how children learn and more concerned with how children learn to solve real problems and carry on purposeful activities. Considerable research has been directed toward audio-visual aids to learning. Especially in the teaching of elementary science, radio broadcasts and motion pictures were found useful in changing the behavior of boys and girls. The last five years have also included studies such as that of Greene (11) showing the effectiveness of learning through activities which are meaningful to children.

Needed Research

Especially worthwhile would be studies of changes produced simultaneously in understandings, critical thinking, attitudes, and overt behavior. Such studies can be carried out more easily when further tests and other research tools become available. Further research concerning survey courses in science and functional courses in mathematics at the secondary-school level is needed. The problem of what curriculums are most suitable for preparing teachers especially competent in mathematics and in science offers many angles to be investigated.

The participation of the United States in the present world war creates new areas for educational research. Already there has been much revision of present curriculum materials and much preparation of new materials, especially in science areas. The furthering of "air-mindedness" has brought curriculum modifications; so has the program of the Office of Price Administration with its advocacy of changes in consumer habits. The effectiveness of such curriculum materials should be studied.

Brief mention of aspects of the present emergency closely related to the teaching of mathematics and science is in order. At present, two national objectives are to win the war and to aid in laying a suitable foundation for an improved world in the postwar era. For students approaching draft age, specialized vocational needs in science and mathematics must be considered. For those less close to military age there is need for general education pertinent both to the present and to the postwar future. The educational problem involved in providing for a better world is no small one. Among the many areas in which more complete understanding is needed are: (a) health, as shown by the fact that 45 percent of those applying for military life were found to be physically unfit; (b) American capacity to produce materials and energy, to regulate their flow through communities, and to consume their finished products; (c) biological and social aspects of the human life span from childhood, through adolescence and youth, into adulthood, and then old age; (d) world-view, as developed through use of scientific methodology; and (e) intercultural and interracial problems, including those arising from classes and castes and from linguistic differences. The facing of such problems with our students today will make it easier for them to face these problems when they become adults.

Teachers of mathematics and science are challenged by current problems of society to be as effective as possible in their classroom teaching, in their guidance contacts with students, and in their community responsibilities. Research workers are challenged to ascertain what curriculum materials and methods are most appropriate for boys and girls in a world at war, and later in a world seeking a more stable form of organization.

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CHAPTER II

Teaching of Science in Grades I through VI

FRANCIS D. CURTIS

RESEARCH IN THE TEACHING OF SCIENCE at the elementary-school level is less abundant than that at the junior and senior high-school levels. Two plausible reasons to account for this fact are that science is not yet established as a major area in the elementary program of studies, and that elementary-school teachers as a rule are not so well trained in the subject-matter of science as are the teachers of the junior and senior high schools. It is encouraging, however, to note the appearance of an increasing number of studies of significance and merit in the teaching of elementary science.

Trends and Objectives of Elementary Science

Underhill (15) conducted an extensive historical investigation of the development of the elementary science program since 1910. He divided his survey into six chronological periods and attempted to determine for each period the trends with respect to the objectives of elementary science and the ways in which educational theory has influenced the selection, organization, and presentation of materials of the elementary-school program. He pointed out the objectives of modern elementary science as being concerned primarily with teaching generalizations which function directly in thinking, with scientific methods of thinking, and with scientific attitudes. He pointed out also that "leaders in general education have recently stressed the place and significance of science . . . in daily living"; but that "in spite of such emphasis, specialists have given little help to the teacher in formulating specific programs to realize these potentialities." He concluded that the approach to the curriculum of elementary science lies in providing situations within which the learner may have the opportunity for problem-solving activities on problem situations which are significant to the children and at the same time are significant for the future.

Zintz and Kambly (16) made a critical analysis of 106 recently published units of elementary science found in twelve educational periodicals. They found the general objectives of elementary science to include the development of scientific attitudes and training in the use of scientific method. The teaching of scientific principles, so prominently stressed in recent research reports and authoritative books and articles, as a major objective of all courses of science at the elementary- and secondary-school levels, did not appear as an objective in these sources. The chief teaching emphasis was placed on arousing and using children's interests.

Evidence of the importance of teaching principles of science as a major objective of elementary science was presented in an investigation by Hankamp (8), who concluded that the present tendency is "to decrease the

long list of general aims to two or three major goals of instruction and to state specific objectives in terms of large subjectmatter generalizations." Russell (14) secured the opinions of fifty-one "well-known educators" relative to various aspects of elementary science, employing a questionnaire of fourteen parts. The opinion of this group was that elementary science should not be concerned with mere fact-getting but that it should be developed with primary emphasis on teaching important principles, developing scientific attitudes, and using scientific method. The incidental teaching of science meets with majority disapproval. Almost three-fourths of this group favored the organization of units around concepts rather than around topics.

Curriculum of Elementary Science

Investigations of the materials which are now found in, or which should be included in, the elementary science program are more numerous than studies of any other kind in this field. Only a few of the more significant or typical ones can be mentioned in this brief review. Probably the most elaborate and extensive investigation of curriculum materials of elementary science is that by Bruner and others (4). This study included the analysis of forty-two courses "judged outstanding" by the Curriculum Bureau of Teachers College, Columbia University, and distributed fairly evenly among Grades IV, V, and VI. Practically all these courses were found to include unit materials on astronomy and earth science—two aspects of science that are almost universally included in courses of general science but which are rarely found in the courses at the senior high-school level. The investigators found no evidence of a sequence of materials in science planned for the intermediate grades, a condition which they attributed to the lack of scientific evidence relative to the placement of materials. The environmental approach was found to be the one most frequently used in these courses in science for the intermediate grades.

Zintz and Kambly (16) also found that the units analyzed in their study reflected a tendency to make extensive use of the immediate environment. Like Bruner, moreover, these investigators found little agreement with respect to the placement of units when they analyzed 106 recently published units of elementary science.

Fish (6) investigated the content of six health readers, nine science readers, and twelve general readers, written for Grades I, II, and III. She analyzed the materials for scientific facts which she classified under the following eleven headings: animals, plants, earth science, astronomy, weather, making work easy (fire, electricity, details of modern invention, and mechanical progress), neatness and cleanliness, safety, nutrition, care of the body, and mental hygiene. She found that the median numbers of scientific facts per page were 3.4 for the science readers, 2.2 for the health readers, and 1.2 for the general readers. She found that the books as a whole contained not only more stories about animals than about plant life

or physical materials but also about two and one-half times as many scientific facts about animals as about plants. The major proportion of the facts in the health readers dealt with care of the body, cleanliness, and nutrition.

A significant recent shift in the point of view with respect to the sources of material which should make up the content of elementary science is revealed in Hankamp's study (8). She stated as one of her major findings that specialists in science education are "almost unanimous" in their conviction that some aspects of all the fields of scientific knowledge may be taught to elementary-school children. This statement reveals the present trend for a broad program of elementary science to supplant nature study which formerly constituted most of the science taught in the grades and which still persists as the sole offering in many elementary schools.

Palmer (13) reported a survey of the teaching of science in the elementary grades of 154 communities in 26 states. Unfortunately the report failed to include descriptions of the various phases of the study or of the technics employed in investigating them. Some of the findings, however, especially those dealing with definite provisions for instruction in elementary science, are of interest as indications of modern trends. Palmer stated that 110 of the 154 communities provided a definite time in their programs for the teaching of science in the elementary grades. Florida was found to lead all the other states represented in the study in the number of minutes devoted to elementary science. The subjectmatter topics most prominently emphasized in the sources analyzed were conservation, health, and humaneness. The lack of details in the report prevents a comparison of the findings of this study with those of earlier studies of the status of elementary science, such as those by Patterson and Palmer.

One factor which has long hampered the expansion of the elementary science program is the meager training possessed by the average elementary teacher in the various fields of science. Realizing this lack of fundamental knowledge of science on the part of teachers, administrators have hesitated to introduce elementary science into the grade-school program; and many elementary teachers fearing to venture into unknown fields have sturdily and effectively resisted all movements to expand the elementary science curriculum. Hankamp (8), however, from her survey of professional literature on the teaching of science, found evidence that the regular room teacher is capable of teaching elementary science, if she can be aided by the counsel of a specialist in science.

Trends and Innovations in Teaching Practices

Significant chiefly because of its emphasis upon the modern shift away from conventional teaching materials and practices is the study by Greene (7) of the relative values of teaching science with and without the use of plays. He placed 405 fifth-grade children under 40 teachers in three pairs of groups "as nearly equal in size as geography and their own choice would

permit." Each teacher taught first a "nondramatic" unit by more or less conventional methods and then taught a dramatic unit with which a play was the major activity. Of the six plays used with the "dramatic" units, four were written by teachers and two by the children who filled in outlines supplied by the teachers. Two of the six plays were written for child actors, two for marionettes, and two for both child actors and marionettes. The investigator found little difference in the amount of factual information learned by the two methods. He concluded that if only gain in factual information is wanted, the dramatic method will not justify the expenditure of time required in its preparation and presentation, but that the greater interest aroused by the dramatic method justifies the greater expenditure of time. Better results were secured when the pupils wrote their own plays than when the teachers wrote them. More desirable traits and attitudes were furthered by the dramatic than by the conventional methods, and the dramatic method lends itself readily to the correlation of science with other subjects.

Arnold (1) used 90 fifth- and sixth-grade pupils for his experimental group and 83 for his control group. With the experimental group he used a "problem-discussion" technic with 25 items, which are found to be similar to some of the types used earlier by Curtis in his Test of Scientific Attitudes. Arnold arrived at these conclusions which are pertinent to the teaching of science: In terms of average growth the experimental group in three months of learning to use scientific thinking made growth which would have taken nine months without instruction. ". . . this study supports the hypothesis that critical thinking can be taught in elementary schools whenever time is taken to give adequate consideration to our purposes and procedures." This last statement agrees with the conclusion of Weller from her earlier study of attitudes and skills in problem-solving with sixth-grade classes in elementary science. Also the results of this study supplement in a valuable way those of Croxton's and Haupt's earlier studies of another phase of the objectives of science teaching, namely, the teaching of generalizations. Both these investigators found that children of all six grade levels were capable of making generalizations.

Bailey (2) made a pioneer attempt to ascertain the difficulty which children experience in comprehending scientific concepts discussed in textbooks at both elementary- and secondary-school levels. The subjectmatter area investigated was that dealing with power. The investigation extended through 20 fifty-minute periods; the degree of understanding of "power" was measured by a specially constructed test of facts and principles, administered at the beginning and the end of the investigation. The investigator concluded that "science concepts pertaining to power cannot be satisfactorily developed by pupils with a mental age of 160 months or less."

Mullen (12) worked with four hundred children in five grades of elementary schools in New York City to determine their reactions to certain living animals. Each child studied the same animal for fifteen minutes on

each of three successive days. The questions asked and the comments made were recorded and subsequently analyzed. Mullen concluded that while all children carry on perceptual thinking, only about 6 percent of the children involved in her study attempted to solve problems which they themselves had raised, and that only about 3 percent made generalizations. This study is reminiscent of Finley's pioneer study of children's reactions to a mud-puppy, but it reflects modern trends in the teaching of science, namely, emphasis upon reflective thinking, problem-solving, and the making of generalizations.

Investigations of the Value of Radio and Films

Two studies of the values of the radio as a teaching aid deserve special mention, those by Brewer (3) and Miles (9). Brewer (3) worked with an experimental group of 795 children in 25 classes and a control group of 859 children in 27 classes, all in schools of New York City. He used five broadcasts based on certain concepts or aspects of nature. With an elaborate and careful statistical technic he secured results which led him to conclude that "radio programs do serve as a definite stimulus to further activities." He found also that there was some gain by the experimental groups in factual information and in the understanding of concepts either as a direct result of the broadcasts or of the stimulus they provided.

In the second study Miles (10) attempted to determine the effects of broadcasts upon increasing the children's knowledge of problems of conservation of wildlife and natural resources, and in developing both interests in conservation and attitudes favorable to it. The experimental group consisted of an unselected and probably representative sampling of city children in 5 fifth-grade and 4 sixth-grade classes, and the control group of 10 similar classes, equated approximately with the experimental classes on several bases. A series of 13 broadcasts specially prepared by fifth- and sixth-grade teachers of science was used with the experimental group. The results of specially constructed tests administered twice during the year indicated statistically reliable evidence that the use of the radio resulted both in an increase in information and in a shift of attitudes. With respect to the development of interests in conservation, Miles found that "the amount of time devoted to utilization (that is, to considering the materials discussed in the broadcasts and to engaging in activities related to the broadcasts) was an important factor in developing the pupil's interest in conservation." He also found that the radio classes which "spent the most time in utilizing the broadcasts were the only radio classes showing a gain in interests." These results would seem to add evidence in support of the general thesis that desired outcomes cannot be expected to result incidentally but must be planned and taught for specifically.

Experiments to determine the values resulting from the use of films at the elementary-school level have been rare. Cobbs (5) reported such a

study. He used three experimental groups and three control groups made up of children in Grades I to IV in 6 schools. Both experimental and control groups studied the same 3 units for the same length of time under their regular teachers. The experimental groups devoted 30 minutes per day twice a week for 6 weeks to viewing talking pictures on aspects of natural science. The teachers of these groups were supplied with handbooks to supplement each unit of instruction. The teachers of the control group were permitted to use any teaching aids they wished other than the films and the handbooks used by the teachers of the experimental groups. Tests used to measure both immediate and delayed recall revealed consistent gains by the experimental groups over the control groups. No differences in learning by the two sexes were discovered.

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CHAPTER III

Teaching of Science in Grades VII, VIII, and IX

FRANCIS D. CURTIS

Scientific Interests at the Junior High-School Level

STUDIES OF CHILDREN'S SCIENTIFIC INTERESTS have always had a prominent place among research investigations because of the guidance their findings may provide in the selection of basic or supplementary curriculum materials. Zim (30) reported an elaborate and extensive study of the interests and activities of "younger adolescents," chiefly in the seventh, eighth, and ninth grades of four schools. He gathered his data from a series of analyses: (a) answers to a questionnaire based on 184 topics grouped into 29 scientific and 5 miscellaneous categories; (b) English papers written by 1,161 boys and girls on "The Thing I Would Like To Do Best in Science"; (c) preferences expressed and questions asked by 65 classes viewing 9 science exhibits for 10 minutes; (d) choices by 1,114 boys and girls of science films involving use, understanding, and manipulation; (e) responses by 762 boys and girls to a questionnaire based on 107 questions "which adolescents might wonder about"; (f) 667 additional questions written upon the questionnaire blank by the respondents; and (g) several hundred individual entries in science fairs. Zim concluded that the interests of adolescents are expressed through acceptable channels of science; that adolescent interest is typically expressed in relation to a specific phase or topic of science rather than to general areas or school subjects; but that school science does not seem to be an important source of adolescent interests. He found that boys and girls exhibit definite differences in scientific interests, activities, and preferences; but that both sexes exhibit strong preferences for science related to health, growth, reproduction, and animal life.

Ruffner (22), using a technic not adequately described, with parallel groups "as nearly alike in all respects as possible," sought to determine pupils' interests in general science and to measure the changes of their interests within a given time. From her data she concluded that there is sufficient permanence or stability of the scientific interests of pupils to serve as a major criterion for the selection of subjectmatter in general science for the eighth or ninth grades. This conclusion agrees in general with that of Zim (30) who stated that "adolescent interests are permanent enough to warrant use in the curricula if justified on educational grounds." The conclusion contrasts sharply, however, with that which Fitzpatrick based upon the results of an earlier extensive study in which he found pupils' scientific interests so unreliable as to render grouping of subjectmatter material upon the basis of interests "of dubious value."

Another aspect of pupil interests relates to the difficult and important problem of motivation. Teachers of science in the senior high school are frequently heard to complain about the difficulties they have in motivating their courses in special fields of science because the interest of the pupils has been dulled as a result of their having studied general science. Similar complaints of the diminished interest of pupils in general science as a result of their having studied elementary science are rarer. Nevertheless this latter situation influenced Matteson and Kambly (19) to investigate the extent to which material covered in the usual seventh-grade course of general science has been acquired by pupils before entering the seventh grade and to determine also the gains made in general science by pupils who had been taught science in the elementary grades over those who had not. A test of 199 questions, chiefly factual, was administered to 573 seventh-grade pupils, some of whom had studied science in the elementary grades and the rest had not. The administration of the test preceded all work in general science. The investigators found little difference between the scores of the two groups; that is, they found no evidence indicating that topics had been adequately covered in the elementary schools. They recommended that teachers emphasize the cyclic arrangement of subject-matter, and the need for review along with the study of new materials.

Analyses of General Science Textbooks

More than twenty years ago Howe used data which he secured chiefly from an analysis of textbooks in an attempt to answer the question, "Can and should general science be standardized?" Several recent analyses of textbooks present evidence with respect to whether the content of general science has yet been standardized. Graham (9) selected 19 units from Curtis' *Synthesis and Evaluation of Subject-Matter Topics of General Science* (1929) and divided these units into 124 subdivisions. He then compared the content of 8 recent textbooks of general science with these subjectmatter subdivisions to determine the extent to which the books conformed with the list from the synthesis. Graham also computed the number of square inches of space devoted in each book to each topic. He found that five of the textbooks devoted space to all 19 units and that the remaining three devoted space to 18 of the 19.

Simmons (24) analyzed the content of 4 textbooks of general science for each of four chronological periods. He computed the "percentages of space" devoted to each unit. He found that 16 units predominated in the books of all four periods. Both Graham and Simmons concluded that authors of modern textbooks of general science are generally agreed upon what materials should constitute the texts. This conclusion agrees with that of Davis but contrasts sharply with that of Wolford, both of whom analyzed textbooks of general science of a not much earlier period. Wolford

stated that "there is very little agreement among writers as to what should be included" in a textbook of general science.

Evidence that the contents of the separate books of three-book series of general science are not standardized is presented in several studies. Pettit (21) analyzed the content of 5 seventh-grade, 4 eighth-grade, and 4 ninth-grade textbooks of three-book series to determine the degree of uniformity of content with respect to units, topics, and basic concepts in corresponding books. From his detailed findings he concluded that there is "little agreement among the authors of the several books as to what content should be included at the various grade levels and in the definite subject-matter areas." Vander Ploeg (26), LeCocq (13), and Huffman (12) made companion studies similar to that of Pettit of, respectively, seventh-grade, eighth-grade, and ninth-grade science textbooks of three-book series intended for the junior high school. Vander Ploeg and Huffman found a distinct lack of uniformity in the content of different seventh- and ninth-grade books, but LeCocq reported a considerable degree of such uniformity in the eighth-grade textbooks of three-book series. From these various studies it would seem that single textbooks of general science probably agree more closely in content than do corresponding volumes of three-book series.

Vocabulary burden—Some evidence of the nature and the appropriateness of the vocabulary used in textbooks of science is found in a summary by Curtis (5) of a hundred separate investigations (most of them master's theses) of the vocabulary of textbooks of science for the junior high school and senior high school. The combined data of the studies dealing with general science are interpreted as indicating that the vocabularies of textbooks of general science are too difficult for the pupils for whom the books are intended; that the textbooks contain many technical and nontechnical words, the meanings of which the pupils do not know; that there is too little repetition of both scientific terms and difficult nontechnical words; that difficult nontechnical words constitute too large a percentage of the difficult vocabulary of textbooks of general science; that not enough of the scientific terms used in such textbooks are defined; and that too frequently the definitions fail to appear in the books until the words have been used several times. The conclusion that the vocabularies found in textbooks of general science are too difficult agrees with similar conclusions reached by Powers and Pressey in their pioneer studies published more than ten years earlier.

Despite militant advocacy by educational leaders of the use of many sources of subjectmatter, not much progress in this direction seems as yet to have been made. Graham (9) found that only one textbook of general science was used in 87 percent of the schools to which he sent his inquiry. A decade earlier, Curtis, in a study of the teaching of science in the schools of the North Central Association, found 89 percent of the teachers of general science using only one textbook.

Progress in Developing Scientific Thinking

The importance of developing scientific attitudes in pupils of all grade levels has been stressed so persistently in the *Thirty-first Yearbook* and in other authoritative sources that it has become widely accepted as a major objective of science teaching. How successfully scientific attitudes can be "taught" has not yet been determined unequivocally by research evidence, one reason being that entirely satisfactory tests of scientific attitudes have not yet been devised.

Eberhard and Hunter (6) attempted to discover the extent to which scientific attitudes could be developed through direct teaching. They used three groups paired approximately on the bases of mental age and sex. Group I was studying general science; Group II had previously completed a year of general science in which little or no emphasis had been placed upon scientific attitudes; and Group III had had and was having no instruction in science. Group I received 7 months of instruction in which every effort was made to teach the various scientific attitudes specifically and thoroughly. Comparisons of the groups were based upon scores on Hoff's "Test of Scientific Attitudes." The investigators found no evidence that their attempts to teach scientific attitudes resulted in developing such attitudes. They expressed doubt concerning "the ability of changing the skill in science thinking through classroom teaching procedures carried on for the time given in this experiment."

Blair and Goodson (3) attempted to determine the results of direct teaching of several of the scientific attitudes and various elements of scientific method. They used three groups of ninth-grade pupils: Group I, composed of 32 pupils, was given, along with the regular course in general science, specific training in scientific thinking; Group II, composed of 49 pupils, was taking a course in general science taught according to usual methods; and Group III, composed of 89 pupils, was not studying science at all. Results were measured by scores on Noll's "What Do You Think?" Form 1. These investigators found in contrast with Eberhard and Hunter, a marked improvement in scientific thinking secured through the general science course "when special attention is given to obtaining this outcome and when specialized learning exercises . . . are utilized."

Further evidence bearing indirectly upon the teaching of scientific attitudes was secured by McKnelly (16) from his study to determine the values derived from free reading. This investigator used 48 pairs of pupils in 4 ninth-grade classes matched approximately on the bases of sex, IQ's, and scores on the Ruch-Popenoe General Science Test, Form A. During 8 months, the experimental group devoted one period per week to free reading in general science, while the control group spent the corresponding period in detailed discussion of science materials. Subjectmatter tests and Curtis' "Test of Scientific Attitudes" were administered at the end of the experimental period. All the results, though not statistically significant, favored the experimental group. McKnelly interpreted his findings as

indicating that scientific attitudes should be taught directly if they are to be the outcomes of science teaching. This conclusion agrees closely with that of Curtis and of Blair and Goodson (3). The latter two stated that "the mere study of general science does not in and of itself make a unique contribution to the development of scientific attitudes."

Scott (23) reported a study which involves such scientific attitudes and elements of scientific method as making observations, drawing inferences, and weighing evidence. A class of junior high-school pupils made first a study of the advertising of automobile batteries, then individuals and small groups made dissections and other studies of batteries by means of laboratory projects of various sorts. Later they checked against the advertising claims the observations they had made during these activities. Scott concluded that the average junior high-school boy is likely to be impressed by the "massive type" of advertising and to accept misleading generalizations in such advertising, but that he is willing and can be trained to seek out the facts. The investigator expressed the opinion that a study of advertising is worthless unless it be accompanied by laboratory methods to stimulate interest and to aid understanding.

Superstitions—Studies of superstitions and unfounded beliefs in general are important because superstitions are involved in the scientific attitudes. A considerable number of studies of superstitious beliefs, conspicuously those by Caldwell, Lundeen, Zaph, Salt, Weller, and Maller, have been contributed during the past decade. Three recent investigations merit addition to the list. Vicklund prepared a six-week unit on superstitions using for the background Caldwell's and Lundeen's list of unfounded beliefs. He taught this unit to 135 pupils in 4 classes of general science, giving the same test at the beginning and at the end of the experimental period. His major conclusion confirms the important one reached earlier by Caldwell and Lundeen, namely, that superstition and other unfounded beliefs can be diminished by direct teaching of facts. He reached the further conclusion that the most difficult false beliefs to remove are those related to health and mental telepathy because "they are deeply rooted in religion and other emotional areas." Salt had reached a similar conclusion earlier with respect to false beliefs related to health. The importance of misconceptions with respect to health is emphasized in the results of a study by Hancock (10). This investigator secured the help of 53 selected judges (subscribers to *Science Education*, authors of articles in that journal, members of the National Association for Research in Science Teaching, and experienced science teachers) in evaluating certain popular misconceptions in science. Their combined judgments indicated that certain misconceptions relative to health have "greater potentialities for affecting the behavior of the believers than the other misconceptions submitted for evaluation."

The third study of this group, one by Ter Keurst (25), was planned to measure the degree of acceptance of superstitious beliefs pertinent to personality adjustment, by 237 white boys, 212 white girls, 70 colored boys,

and 62 colored girls in Grades VII, VIII, and IX. From an analysis of original sources he obtained a checklist of 92 beliefs which were judged to be of high relative significance by 7 specialists in psychology. From the results obtained by administering this checklist, Ter Keurst concluded that belief in superstitions does not decline with advance in grade level. He found the "mean percentages of acceptance" much greater among the colored pupils than among the white. These results agree in general with those found earlier by Salt. Ter Keurst found that the "superstitions most prevalent referred to the animistic role of Nature, supernatural manifestations, and deterministic viewpoints of life."

Exploring and Providing for Individual Differences

Little investigational evidence is yet available to assist the teacher in solving the important and puzzling problems resulting from the individual differences of pupils. A valuable contribution to this area is that of Beauchamp (2), who had for his major objectives the determination (a) of the nature and extent of individual differences in attaining specific learning products in science; and (b) of the factors influencing the progress of pupils in the attainment of specific learning products. His subjects were 21 unselected "subfreshmen of the University of Chicago High School who were found from the results of a battery of tests to be superior in intelligence and in rate and comprehension of reading, and to represent a wide range in experiential background and quality of application." The materials used in the experiment were four units of science organized and administered in accordance with the Morrison Unit Plan. Beauchamp's conclusions emphasize the complexity and difficulty involved in teaching and learning. He stated that though progress in the study of science is definitely related to intelligence, ability to read, experiential background, and sustained application, there are so many exceptions to this general relationship that individual progress can be interpreted only in the light of observations of the pupil's methods of work. He stated also that the learning situation is both extremely complex and in a state of constant flux, with the result that it is practically impossible to isolate one factor and definitely determine its causal effects. His further conclusion that individual differences affect pupil progress more than the method of teaching does affords an interesting comparison with the conclusion made earlier by Corbally who stated that the determining factor is the *teacher* and not the method or device.

The third part of Beauchamp's study, to determine the effect of instruction in learning to make comparisons, is an extension of his first major investigation in teaching study habits published earlier, and indicates, as did the other, that direct instruction in study habits pays substantial dividends.

The value of individual help given by the teacher to each pupil as a means of providing for individual differences is indicated in a study by

Olson and Kambly (20) of the relative effectiveness of three types of teacher activity during the directed-study period. The investigators worked with three "nearly equivalent" groups of pupils in ninth-grade general science, using for the instructional materials units organized and taught in accordance with the Morrison Unit Plan. Conditions with the three groups were controlled so that only the teacher-activity varied with the groups. The pupils of one group worked together aided uniformly by the teacher; the pupils of the second group worked individually while the teacher proceeded from pupil to pupil aiding each, whether or not the pupil asked for help; the pupils of the third group received help from the teacher only when they requested it. The investigators found that the individual method resulted in the greatest amount of factual learning and that the "help requested" method resulted in the least. They noted a tendency in the "group" method for some pupils to depend on the more able pupils of the group.

Trends and Innovations in Teaching Practices

Studies of methods and materials by means of which to enrich and supplement courses of science are stimulating and valuable. Several such studies deserve mention in this brief review. Carpenter (4) reported a study in which 40 recordings of science lessons were listened to on the radio by approximately 11,000 children in 307 general science classes in 136 cities and towns of 36 states. Bulletins containing suggestions of teaching devices and tests based on the records were distributed for the teachers' use. The results from the suggested procedures employed with the recordings were determined from opinions and comments by teachers and supervisors, extracts from pupils' letters, and the results of a final test on factual information. The findings were interpreted as indicating that through the use of the recordings the pupils gained confidence in the scientific method and its findings; that their interest in science was stimulated; and that their growth with respect to certain of the scientific attitudes was increased.

Hollandsworth (11) analyzed the activities of a summer camp to find ways in which they contribute to the science course through affording background and experience useful in relation to the work in general science. The activities of camp life were compared with a list of topics under 21 units obtained from the three-year outline of general science for Grades VII, VIII, and IX in the Pennsylvania Course of Study for 1933. Hollandsworth concluded that a summer camp "offers a wide background of experience for a general science course through 62 percent of its activities." Also he found that 75 percent of the topics that are included in a course of general science were found in normal camp activities.

The growing trend toward the integration of subjectmatter fields with out-of-class experiences finds some support in the results of a recent study by Word and Davis (28). These investigators attempted to measure the acquisition and retention of factual information by seventh-grade pupils

in a general science course. Using 3 groups of pupils, they administered a test at the beginning and a second one at the end of each of 9 two-week intervals. The repetition of the second test at the end of each following interval made possible the determination of retention. From the data secured the investigators concluded that pupils retain more readily the materials of general science which relate to particular interests, hobbies, or out-of-school environment, and to materials related closely to those presented in other courses.

Use of Silent and Sound Films

The values of motion pictures as supplementary aids to instruction have been convincingly established by numerous research investigations in several fields. McCowen (15) contributed a carefully controlled experiment of this kind in which substantially better (though not statistically reliable) results were secured with films and slides with a seventh-grade class in general science than were secured without these supplementary visual aids with an "equivalent" class. The relative values of sound and silent films or of the use of films as a substitute for other teaching practices or materials of instruction, however, have not yet been determined though often investigated. Maneval (18) contributed evidence with respect to the relative values of sound and silent motion pictures in teaching science to eighth-grade pupils. He employed the unusual device of using the same educational sound motion pictures with both experimental and control groups but eliminated the sound and used captions with the control group. His experimental and control groups consisted each of 152 pupils paired on the bases of mental age, sex, and reading ability. Eight pictures were shown with 4 units of subjectmatter. On the whole the results shown by tests, though not statistically significant, favored the silent films both for immediate and delayed recall. The investigator concluded that pupils of higher mental ability learn better with silent films, but that those of lower ability learn better with sound films.

Maneval (17) contributed evidence also with respect to the relative values of the use of sound motion pictures and of printed study sheets made to resemble science textbooks and workbooks. From eighth-grade classes in general science he selected 2 groups, each composed of 140 pupils, paired on the bases of mental age, sex, and reading ability. He rotated the groups after each 30-day period of instruction so that each group was taught two units with films and two with study sheets. With all four units the results of tests measuring immediate recall of factual information showed statistically significant advantages in favor of the use of the study sheets over use of the sound motion films; and with three of the four units the test results for delayed recall likewise showed advantages favoring the study sheets. None of these advantages, however, was statistically reliable.

Some evidence of the unreliability of pupils' judgments with respect

to the relative values of teaching methods is supplied by the responses of the pupils with whom Maneval experimented. Responding to a questionnaire, 63 percent stated that they thought they had learned more from films than from study sheets. Seventy percent of the pupils expressed a preference for the film method over the study-sheet method.

Workbooks

The trend to use workbooks, though widely followed, has recently received much vigorous condemnation. Not much investigational evidence, however, has yet been secured which indicates the desirability either of using or of abolishing workbooks. Anderson (1) reported an experiment with two "equivalent" groups, each of 40 students, with which he tried to determine the effect of the use of a workbook on achievement in general science. The results showed greater progress by the group using the workbook, and showed also that the pupils of higher intelligence tended to profit more from the use of the workbook than did those of lower intelligence. This latter finding agrees with that of Peterson and Douglass in their earlier study of the effects of using workbooks with general science classes.

Morrison Unit Plan

From the time of the first published investigation of the relative values of different methods of teaching science, that of Gilbert in 1910, there have been numerous learning studies of this type. A recent one by Forsyth is interesting because of its bearing upon the trend toward a less extensive use of the Morrison Unit Plan. Forsyth investigated two methods of teaching general science with two groups of eighth-grade pupils, one a group of 40 pupils who had made superior marks, and the other of 25 pupils who had poor achievement records. He rotated the teaching methods 5 times during a semester. He taught one group by a "study-assignment" method in which he gave a definite assignment for study followed with recitation, discussion, and test; he taught the other by a "lesson-guidance" method in which he used the Morrison Unit Plan. At the end of each rotation he administered to each group a test of factual information. He obtained statistically reliable results in favor of the use of the unit plan with the superior pupils and favoring the conventional method for the duller pupils. This study goes a step beyond Corbally's somewhat similar earlier experiment in which no advantage was found in favor of either the use of the unit plan or the employment of conventional procedures with mixed classes in general science.

Concluding Comments

In reviewing the research investigations in the fields of elementary- and junior high-school science for the period covered by this volume one is

impressed by evidences of several trends: (a) There is an increasingly strong emphasis upon the teaching of principles of science, the developing of scientific attitudes, and the training in the use of the elements of scientific thinking—as major objectives of science courses at all levels through the elementary and junior high schools. (b) There is a large proportion of investigations, the findings of which add validity to the thesis that the desired outcomes of instruction are not secured incidentally or accidentally but can be insured only by teaching directly for them. (c) There is marked evidence of the movement away from conventionalized materials and procedures toward enrichment and supplementation of content, devices, and materials.

On the whole the investigations of this period for the levels here reviewed are of a higher degree of excellence than are those of similar earlier periods for the same levels. There is a marked improvement of investigational technics employed, especially in the learning studies. There are still many studies in which inexcusably crude technics are used, but the number of such studies is decreasing.

One cannot help decrying the fact that investigations of major significance remain unpublished while many others of mediocre importance and merit are reported in our best educational magazines.

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CHAPTER IV

Teaching of Mathematics in Grades I through VI

WILLIAM A. BROWNELL and FOSTER E. GROSSNICKLE

Summaries, Yearbooks, Bibliographies

TWO SUMMARIES OF RESEARCH, not merely for the past few years but from the earliest to recent studies, were printed. The one by Buswell (35) is practical in nature and is intended to give teachers brief answers to some of their most pressing problems. Altogether eighteen questions were asked and were considered in the light of research but without specific citations, each in approximately a page. Wilson's summary (134) is much more extended (about 10,000 words). Its purpose is to show what research in arithmetic "adds up to," not alone for the teacher but for the student of the curriculum and of research methodology as well. A list of 115 references, all of which are cited in the body of the chapter, concludes the report.

Buswell continued his practice of supplying short annotated bibliographies covering some of the research studies for the preceding years (36). The five latest in this series of selected bibliographies, 1937 to 1941 inclusive, average about eighteen references a year.

The National Committee on Arithmetic of the National Council of Teachers of Mathematics published its final report, *Arithmetic in General Education* (77). Besides the Introduction by the chairman, Morton, who in 1938 had stated the Committee's point of view in arithmetic (73), this yearbook contains fourteen chapters. Two of the chapters are bibliographies. Stretch (102) listed one hundred carefully chosen research studies, and Bond (9) one hundred critical, theoretical, and practical articles. Wren's chapter (141) consists of 168 questions addressed to teachers and designed, not for the purpose of self-evaluation, but as "shockers" to dispel self-complacency on their part. Other chapters in this yearbook which are pertinent to the topics of the present summary but which are not referred to elsewhere are those by Brownell and Grossnickle (18), "Interpretation of Research"; by Buckingham (31), "What Becomes of Drill?"; and by Buswell (34), "The Function of Subject Matter in Relation to Personality." The last named reference is particularly important since it refutes (but in a positive way) the commonly heard charge that the mastery of subjectmatter in general and of arithmetic in particular is inimical to a well-adjusted personality.

Studies in Arithmetic by the Scottish Council for Research in Education (93) is composed of six excellent researches, which will be considered later in this chapter. Brownell (19) prepared a critical synthesis of printed investigations relating to arithmetic in Grades I and II. Chapter 2 of that monograph brings together studies on the number

abilities of children upon entering school, and Chapter 4 similarly canvasses results of instructional studies in these same grades. Smith and Eaton (98) published an elaborate summary of research on the teaching of arithmetic to pupils of low ability. Their bibliography contains 707 references, many of which are only remotely connected with the subject of their study.

State Courses of Study

According to the *Education Index* the following states published new courses of study during the period here under review: Idaho (62), Kansas (68), New Mexico (79), Oregon (80), and Pennsylvania (82). The last-named course of study was explained and defended by Stadtlander (101), who compared its theory and placement of topics with various textbooks.

Sample Theoretical Articles on the Curriculum

The present and changing function of arithmetic in the elementary curriculum was valuably discussed by several writers; for example, by Breed (12), by Buckingham (30), and by Sueltz (105). In two other important references Buckingham treated the contribution of arithmetic to general education (28) and differences between meaning, significance, and insight as arithmetical outcomes (29). Brueckner (25) emphasized social phases of arithmetic instruction, and Tingley (112) urged the adoption of an arithmetical system with eight instead of ten as the base. Wilson (138) objected to the attempt to derive the arithmetic curriculum or methods of teaching from any so-called "theory" regarding the subject.

Determination of Content (Learning Experiences) through Surveys of Adult Usage and Adult Opinion

Johnson (66) circularized 650 manufacturers, doctors, engineers, and educators to ascertain their opinions with respect to instruction in the metric system. Eighty percent favored general adoption and exclusive use of the metric system; 75 percent felt that the change could be made rather easily over a short period of years and should be effected through education rather than through governmental action alone.

Wilson (138) summarized four master's theses relating to denominate numbers and measures. Three of the studies surveyed the use of such concepts in important industries (silversmithing, jewelry, textile finishing, department store, etc.). The results agreed in showing that comparatively few measures taught in school are used in the trades sampled. The fourth investigation was made with four groups of several hundred subjects each, from grade children to adults, and involved a test to determine the measures known to, and used by, various age and regional classes. It was concluded that measures taught in school are for the most

part forgotten if they are not used and that most people use only a few denominate measures, namely, those in their common experience. It was further concluded that, except for informational purposes as contrasted with computation practice, the instructional load in denominate numbers and measures should be drastically reduced.

Determination of Content through Studies of Children's Knowledge, Uses, Needs, and Interests

Willey (133) summarized in convenient form the principal earlier studies on number knowledge of children entering school, together with more recent investigations relating to their arithmetic uses, needs, and interests. Eight other original studies, part of them covered in Willey's summary, appeared during the period here under review.

Three of the eight studies are inventories of number knowledge. Grant (52) administered Test 5, "Numbers," of the Metropolitan Readiness Tests to first-grade children and reported his data separately for children of low IQ (below 90, N-145), of average IQ (90 to 109, N-252), and of high IQ (110 and above, N-161). The tests included a wide variety of information and skills relating to arithmetic. A similar survey of number knowledge of school entrants was made by Brownell (20) who employed both written tests and individual interviews. New data are combined with comparable data from previously printed studies. Both the Grant and the Brownell studies confirmed the earlier published conclusion that children entering school already possess a large number of quantitative ideas and skills. The significance of such data for instruction is open to question. In Whiteaker's opinion (130) the data do not mean that children may be expected to take on further learnings with economy and ease. Whiteaker's doubts were somewhat refuted by Gunderson's findings (61) in the last of the three inventory studies. Gunderson showed that after a year and a half of experiences carefully planned to develop new meanings and skills her pupils made extensive gains in knowledge and skills.

Five studies were made of ways in which grade children employ arithmetic in out-of-school relationships. Moseley (74) had three groups of sixth-grade children keep "arithmetic diaries." Culver (39) had parents record all their children's questions, problems, and comments regarding quantity and supplemented the data so obtained by more than one hundred visits to homes. Her subjects were aged six to ten. Robinson's investigation (86) also involved arithmetic in the home, as reported by parents. Ellsworth's subjects (47) were children in Grades III to VI, who themselves reported the number of times they used arithmetic and the ways in which they used it each day. Willey's data (132) were obtained in the classroom, from teachers, but had to do with arithmetic outside the regular arithmetic period. The grades included were kindergarten through Grade VI. The findings obtained by Ellsworth will be cited as illustrative

of the findings: of the 53,163 uses reported by his subjects, 27 percent had to do with telling time, 16 percent with using money, 14 percent with counting, 13 percent with reading numbers, 8 percent each with writing numbers and with Roman numerals, 5 percent with addition of whole numbers, 2 percent with subtraction, 1 percent with multiplication, 0.3 percent with division, and so on. In all studies the skills used were found to be simple; fractions seldom appeared; practical measurements were common.

Organization of the Curriculum

In spite of the great interest in the organization of the arithmetic curriculum as revealed by current discussion and by numerous theoretical and practical articles, exceedingly few research studies were reported in this area. The reason may lie, in part, in the ambiguity of terminology. Practically all teachers and students of arithmetic want learning experiences to be "meaningful." But what is a "meaningful" learning experience or curriculum? Johnson (67) described steps taken in revising the Chicago course of study to insure a "meaningful curriculum." Wheat (124) analyzed Johnson's description and concluded that this curriculum could not be "meaningful," and that the means adopted to produce this course of study in themselves must inevitably be inadequate. Similarly, there is little agreement as to what constitutes an "incidental" approach to arithmetic. Buswell (33) analyzed the report of the Benezet (Manchester, N. H.) experiment on "incidental" organization and found the course there to have contained much arithmetic that was taught systematically. Thiele (110), after a visit to the Manchester schools, came to the same conclusion.

Current practices in several "progressive" schools were outlined in one article (85). Samples of units having social emphasis follow. Tompkins and Stokes (113) told how thirteen eight-year-old children learned about the supplying of Philadelphia's food needs. Schaeffer (90) described a particularly good informational unit on time for Grade IV. A unit for Grade V on the ordering and distribution of milk was reported by Welch and Shibles (123); one for Grade VI involving the school newspaper, by Lane (69); and one for Grade VIII on personal accounts, stocks and bonds, and railroads by Russell (87). The reports of Tompkins and Stokes and of Russell are especially helpful in showing the arithmetic actually used in the units.

One investigation (20, Chapter 4) dealt with results of systematic instruction in Grades I and II—instruction oriented with respect to mathematical phases instead of social phases of arithmetic. Rather complete measures were obtained for outcomes relating to number concepts, number combinations, computation, and mathematical understanding, and less complete measures for outcomes of a social character.

Readiness and Grade Placement

Several suggestive articles with respect to grade placement appeared (for example, 21, 33, 43, 103, 104, 140). Brownell (16) briefly summarized and criticized research on readiness under three headings: first-grade inventories, evaluation by testing, and control-group experiments. Brueckner's longer review (22) concluded with a bibliography of fifty-one titles and made several important recommendations.

The outstanding work on grade placement over a period of years has been done by the Committee of Seven, whose experimental procedures and general position with regard to grade placement are well known. The chairman of the Committee, Washburne, summarized the work of his group (119), at the same time proposing standards for the placement of several new topics. The bibliography of thirty-five titles presumably contains all important articles which up to that time had been written by the Committee, by its supporters, and by its critics. In another article (120) standards for placement (really mental age placement) of time and of linear and square measure were reported.

Brownell (14) vigorously attacked both the experimentation and the practical consequences of the Committee of Seven's work. He listed the seven experimental weaknesses admitted by the Committee and then developed two of these in detail in order to show the limitations they impose upon the general adoption of the Committee's standards. He also deprecated the effect of the Committee's research and writings in discouraging constructive efforts to create readiness and in distracting research interest from the study of learning to the less vital problem of placement. Washburne (119) replied to the criticisms with equal vigor. The two articles should be read together.

Johnson (64) reported briefly the effect of Chicago's adoption of the Committee of Seven's placement standards after a few years' trial. In general, marked improvement in pupil achievement resulted. Whether this same improvement might not have been accomplished without the postponement of topics and through the introduction of better methods of teaching, diagnosis, and remedial instruction is not considered. That this possibility is not fantastic was shown by Grossnickle (57) who, in retabulating data previously published by him and criticized by Washburne (119), confirmed his conclusion that under a program of carefully controlled instruction and diagnostic and remedial measures, children can learn division with two-figure divisors sixteen months short of the Committee of Seven's standard of twelve years seven months of mental age.

Brueckner and Melbye (26) analyzed test data to reveal that division by two-figure divisors cannot properly be regarded as a single process to be located for instruction at some one point in the grades. Division examples in which the apparent quotient figure is not the true figure were on the average 39 percent more difficult in Grade VB than examples in

which the apparent figure was the true figure, and in Grade VIA were 23 percent more difficult. Extreme variability in difficulty characterized subtypes as well.

Newman's comparative figures on time allotment for instruction in Scottish and American schools (78) are of special interest to readers of MacGregor's earlier report.[1] MacGregor showed that Scottish children who begin arithmetic at age five instead of six maintain their year's advantage (even add slightly to it) when tested six years later by unfamiliar and ill-adapted American standard tests. According to Newman, Scottish children in the seven years of their primary school have about 8 percent more hours of instruction than do American children in their eight years of elementary education. Another Scottish study, by Curr (40), dealt with placement of "long" division. Curr pointed out the defect of arbitrary mental age standards, showing that with a given mastery standard of 83 percent the minimum mental age for certain examples with divisors of 2 to 12 varied as much as two years. With divisors of 13 to 99 and a 56 percent mastery standard the minimum mental age varied from 10 years 5 months to 17 years 7 months. In view of the extreme interest at present in grade placement, five of Curr's conclusions are paraphrased:

1. For purposes of placement the minimum mental age recommended for a topic is of secondary importance; the chief aim is to determine whether postponement improves or diminishes efficiency of learning.
2. The present study, by using the Committee of Seven's general statistical techniques, confirmed that committee's conclusion that mentally older starters learn better, but
3. The foundations score is a better index of success than the mental age at which the topic is begun, and
4. The reason why the mentally older starters learn better is to be found in their higher IQ's.
5. Over the range of mental ages at which topics are really taught postponement probably makes little difference to learning efficiency, though there is below that range a mental age short of which it cannot be efficiently learned.

Studies of relative difficulty of the processes in terms of their sequence in verbal problems were made by Berglund-Gray (5), by Berglund-Gray and Young (6), by Young and McIsaac (142).

Readiness tests—Gunderson (60) described certain informal readiness tests for primary grades. Brueckner (23) announced the publication of a series of readiness tests eventually to measure the ability of children to attack many new topics in arithmetic. The purpose of the tests is diagnostic rather than purely predictive, in order to enable the teacher to build up essential skills before introducing a new topic. The test for division with two-figure divisors was described, and data were presented to show its validity and usefulness.

[1] MacGregor, Gregor. *Achievement Tests in the Primary School*. London: University of London Press, 1934.

Theoretical and Practical Articles on Teaching Methods

Anderson (1), Brownell (17), and McConnell (70) wrote on the newer views of learning as it relates to arithmetic. Three chapters of the yearbook of the National Council of Teachers of Mathematics were devoted primarily to matters of method, namely, the chapters by Thiele (106), who discussed instruction in the lower grades from the point of view of number interrelationship; by Wheat (126), who dealt with instruction in the middle grades, again from the mathematical point of view; and by Sauble (88), who provided a large number of practical suggestions for enriching the arithmetic course. Polkinghorne (83) compiled a number of brief articles relating to arithmetic instruction in the primary grades, and Bond (9) showed how teaching in other grades as well could be improved through the development of meanings.

Noncomparative Studies of Particular Devices and Technics

In the studies summarized in this section some particular device, technic, or what not was employed with a group of children, and the effects of its use were observed. The reports contain informal accounts, with or without supporting quantitative data, which attest the value of the device. Absence of comparative data makes it impossible to establish the relative merits of the device or technics as compared with alternative procedures.

Dickey (42) described a unique visual aid for the teaching of division by fractions. While he presented no quantitative data to prove its worth, the claims made for it seem reasonable and should stimulate trials by other teachers. Betts (8) reported inconclusive evidence from a study in the sixth grade in which calculating machines were used to stimulate improvement both in computation and in problem-solving. Mackay (71) undertook to test the value of teaching zero as a placeholder instead of as a number.

The advantage of teaching children methods of self-instruction was demonstrated by Wheat and his students. Wilburn (131) taught the easier addition and subtraction combinations to seventy-two children with a mean age of six years and ten months, all enrolled in Grade I in small schools. Forty-seven percent of the children learned all forty-five combinations. Wheat (125) included the Wilburn study with five others which involved the multiplication and division combinations, all taught by methods which encouraged children to discover relationships, arrive at answers, and test answers on the basis of self-responsibility. Achievement in each case seemed to be high.

Wheeler (127, 128, 129) made use of his games (Count-0, Add-0, Mult-0) in order to teach children to read, add, and multiply numbers. Data from the last two studies were utilized to determine the relative difficulty of the combinations but served merely to demonstrate once more

the dependence of difficulty ratings upon methods of teaching. The value of his three studies for instructional theory is reduced by the fact that only a drill type of teaching, happily now on the wane, was employed. An excellent contrast in instructional procedure is offered by Spitzer and Dunfee (100), who described methods to teach meaningfully the division and multiplication facts.

Comparative Studies of Devices and Technics

In seven investigations check groups or other statistical or experimental controls were used in order to compare the advantages of the device or technic in question with those of alternative devices and technics.

Long division—Grossnickle's procedure (56) was analytical and statistical. He compared the advantages of two methods of estimating quotient figures in examples with three-place divisors, namely, the apparent method and the increase-by-one method, and found no advantage for either method. He advised teaching only the apparent method in order to forestall the troublesome decision as to whether the guide figures of the divisor should be increased or not.

Subtraction—Two investigators found experimental evidence in favor of the equal additions method of subtraction. Johnson (65), who had reported several earlier studies of the problem and with similar results, compared the method of equal additions (E) with the method of decomposition (D) and the so-called "Austrian" method (A). In the example 81—47, one thinks, according to method E, "7 from 11 are 4; 5 from 8 are 3"; according to method D, "7 from 11 are 4; 4 from 7 are 3"; according to method A, "7 and 4 are 11; 5 and 3 are 8." Johnson tested in all, 342 children in Grades III to VIII who used method E, 526 who used method D, and 136 who used method A. No difference in time or errors was observable among the three groups on the simple subtraction facts. On harder examples, however, group E surpassed group D in accuracy by a statistically reliable amount and surpassed group A by an amount not quite reliable. As for time, the D group took 16 percent longer than group E and 67 percent more time than group A. When time comparisons were restricted to subjects who made no errors at all on the simple facts, groups E and A maintained their advantages over group D. Unfortunately, Johnson did not report his data differentially by grades. On this account students of arithmetic who concede the greater final efficiency made possible by equal additions but who are concerned that whatever method is taught must be taught in a way which makes the process sensible to learners—such students will remain unconvinced by Johnson's data that the initial method of instruction (Grade III) must be that of equal additions.

Murray's study (75) of subtraction methods comes closer to providing the needed evidence at this point. In his "junior" group, aged eight and nine, were 464 pupils who had been taught the method of decomposition

(D), 842 the method of equal additions (E), and 316 the "complementary" method (C), according to which in the example 81—47 one thinks, "7 and 4 are 11; 4 and 3 are 7." (This last method is therefore unlike Johnson's method A.) Since "borrowing" in subtraction is taught in Scottish schools at ages seven and eight (93, p. 216), the junior group in Murray's study was but one year removed from initial learning. His "senior" group, aged ten and eleven, was made up of 566 users of method D, 835 users of method E, and 274 users of method C. Elaborate statistical treatment revealed that, in all comparisons, both for accuracy and for speed, method E proved most efficient, method C also being superior to method D though not reliably so.

Subtraction provided the basis for a third experiment, in which the method of decomposition alone was taught the subjects, to determine whether a certain "crutch" aided or hindered learning. The results were reported in full by Brownell in a monograph (20) and briefly in a shorter article (13). The crutch was designed to help children understand the nature of borrowing and was found, by a variety of measures, to increase ease and efficiency in learning not only for the dullest children and those least capable in arithmetic but also for the brightest and the most capable as well. Most children tended to abandon the device when they no longer needed it, but the crutch was found useful later on in certain situations, when it was revived—situations in which the child was mastering a new complex task involving subtraction or regaining subtraction skill after a period of disuse. The last chapter of the monograph discusses the significance of the study for learning theory and for arithmetic instruction in general.

Addition—Thiele's investigation (108) related to the teaching of the 100 simple addition combinations by two different methods, the drill method (D) and the generalization method (G). The 270 D subjects were taught each combination directly, separately, and with the attempt to prevent the discovery of relationships. The 242 G subjects, on the other hand, were encouraged to note relationships, to group facts according to generalizations, and to use the generalizations in learning and in correcting errors. The D group was slightly inferior in intelligence to the G group (48 percent as compared with 57 percent had IQ's of 105 or better), but held a slight advantage in knowledge of the combinations at the start of the experiment. On the end test the G children clearly excelled the D children in number of combinations known, regardless of intelligence level and ability to extend their number knowledge to the addition of one- and two-place numbers as well as the addition of two two-place numbers. The advantage of the G method is actually greater than claimed, for the D group had two opportunities to recognize and utilize meanings which are not usually part of the drill procedure of teaching: (a) the readiness program given both groups of children must almost necessarily have made the D children aware of number relationships, and

(b) the combinations were grouped in ways which could have disclosed to the D children the principle that the order of addends (as in direct and reverse combinations) in no way affects their sum.

Problem-solving—Thiele (108) also compared three different methods of teaching children to solve problems: (a) the "association method," according to which children when in difficulty consulted "type" or "model" solutions and corrected their errors with a minimum of help; (b) the "analysis method," in which problems were to be studied in the light of the usual questions, "What is given?" "What is to be found?" and "Which is the correct solution?" and (c) the "vocabulary method," in which the subjects selected from several suggested words the ones needed to make sensible problems for the facts given. A total of 182 trios of fourth-grade subjects were available for comparisons after fifteen weeks, ten minutes a day, spent on the same sets of problem exercises. The "association" group surpassed both the other groups by reliable differences. The conclusion is drawn that it is far better to give children plenty of experience in problem-solving by their own devices than to impose upon them artificial procedures which they cannot understand or use effectively.

Problem-solving was investigated in a different way by Bramhall (11), who was interested in the comparative merits of "conventional" as compared with "imaginative" problems. Seven classes (213 children) spent three class periods a week on imaginative problems, solving them in any way they wished, while the same number of classes (214 children) spent their time entirely on conventional problems. Wheat's earlier study found that children were more successful with the conventional type; Myers' study, with the imaginative type. Bramhall could find no difference in the results of exclusive training with either kind, his measurements being made after ten weeks with several different standard tests.

Diagnosis and Remedial Instruction

Brueckner (23) showed that much research in diagnosing and predicting handicaps in learning may be grouped under four headings: (a) studies in the field of readiness; (b) studies of characteristics of those whose achievement is good or poor; (c) studies of more effective organization and gradation of curriculum content; and (d) studies dealing with the ways in which learning takes place at various stages of the learning process. Samples of these four kinds of study are, in order, 29, 66, 13, and 25.

An important phase of a program of diagnostic and remedial instruction consists in providing proper measures to prevent the operation of factors harmful to learning. Myers (76) and Washburne (118) both stressed the need for greater emphasis on prevention instead of correction of error. Brueckner's readiness tests (24) for this purpose have already been mentioned.

All studies which reported the effectiveness of diagnostic and remedial instruction dealt with the computational phase of number. Moreover, none

of them measured the amount of meaning or understanding which accrues from programs of remedial instruction. Brownell (15) illustrated the kinds of measures which might be secured for this purpose.

Diagnosis of particular difficulties in a given process, followed by remedial instruction, is effective in producing higher scores on an achievement test in that process. Becker's twenty-two sixth-grade children (4) had fewer errors in adding fractions after diagnosis and instruction. Jacqueline (63) obtained similar results from diagnosis and remedial instruction with seventh-grade pupils in fundamental operations, principles of percentage, and problem-solving. A growth in sense of personal responsibility for success and failure in work was claimed. In another experimental group of seventh-grade pupils who had shown weakness on a given unit in arithmetic, Thompson (111) supplied remedial work on needed parts during 10 weeks with approximately a year's gain.

Diagnostic testing devices—Appraisals of various diagnostic tests were collected by Buros (32). Schonel (92) outlined the use of certain diagnostic tests for integers in the four basic operations. Smith and Eaton (96) described a mechanical process for exposing basic combinations to pupils. This device was used in diagnosing errors of seventy-seven fourth-grade pupils. A dictaphone record of the thought processes of the five poorest pupils in working an example was played to each pupil so that he could discover his errors. Eaton (45) discussed the value of the dictaphone record for correcting deficiencies in computation.

Dahle (41) secured repeated elaborate measurements by means of motion pictures, the Iowa Oral Language machine, and a psychogalvanometer from sixteen fourth-grade children at critical stages while learning long division. Important diagnostic values were claimed for the measures, particularly because of their unusual comprehensiveness.

Wilson (135) showed the danger of assuming that all standard tests which seem to have the same function are actually alike, and Brownell (15) discussed the general problem of evaluation of learning, illustrating some of the newer technics.

Error Studies

Shane (91), experimenting with 274 pupils in Grades VI-VIII, found no particular type of error to be characteristic of any mental level. Schonell (92) outlined the kinds of error encountered for each process in arithmetic. Gardner (49) analyzed kinds of errors made by Scottish children in dealing with fractions and compared the number of errors made by American children on the same test. In each of four processes with fractions, the American children made more errors. Thyne (114) analyzed errors made by pupils in the primary grades in connection with the basic facts and found that 65 percent of the multiplication errors resulted from the presence of zero.

The four kinds of examples in division of decimals are (a) dividing a decimal by an integer, (b) dividing two integers with a decimal in the quotient, (c) dividing an integer by a decimal, and (d) dividing a decimal by a decimal. Grossnickle (58) gave a test to about 200 pupils each in Grades VI-IX inclusive and found that type (c) is much more difficult than any of the other types (it being responsible for 45 percent of all incorrect examples) and that placement of the decimal point in the quotient is the most difficult step in the division of decimals.

Constancy of error—An error is constant if it persists; otherwise it is due to chance or a lapse of some kind. Grossnickle and Snyder (59) concluded that all errors on the basic facts, except on zero combinations, were due to chance, their data being drawn from the records of about 100 pupils per grade, Grades IV-VIII inclusive, who five times took the same tests on the facts for the different operations. The number of constant errors was found to be small also in the case of division with two-figure divisors (54). Grossnickle's 221 pupils made 113 different kinds of errors, the average number per pupil being nine during a learning period of twenty-six practices. Furthermore, constancy of error was no more characteristic of pupils who achieved poorly in school than of pupils who did well (57).

Textbook and Vocabulary Analyses

That "mathematics is a mirror of civilization" was shown by Schaaf (89), who made a qualitative analysis of the contemporary social conditions in arithmetic textbooks of an earlier time. In his comparison of eight textbook series, Ulrich (115) discovered considerable agreement among authors as to placement of the basic number combinations and reasonable agreement in the placement of fractions but wide variations with regard to percentage and its applications.

The number of different words and their average number of repetitions were studied for five third-grade textbooks by O'Rourke and Mead (81). About 55 percent of the 296 arithmetical words found appeared five or fewer times, and 24 percent appeared only once in the books in which they were used. Andreen (2) reported that only a few arithmetic workbooks can be characterized as self-administering materials. Waterman (122) offered suggestions for rating textbooks in arithmetic.

Gorman's figures (51) showed that elementary-teachers-in-training need specific instructions on the vocabulary of arithmetic, and Porter (84) gave an altered and condensed form of the Buswell-John Vocabulary Test to Scottish children. Bertotti (7) reported that only 1 percent of the words in six consecutive issues of the *Reader's Digest* were mathematical in character and that about 70 percent of these words appeared in the Dolch list for Grades V-VIII.

Home Study

Further doubt has been cast on the values of home study by four investigations. However, the measures used relate alone to arithmetical outcomes and not to other possible values such as the development of habits of independent work. The study by Crawford and Carmichael (38) was made in Grades V-VIII, that by DiNapoli (44) in Grades V and VII, that by Foran and Weber (48) in Grade VII, and that by Vincent (116) in Grades VI and VII. The results obtained by Crawford and Carmichael are probably typical: a three-year average of home-study classes in one school was 7.43 in arithmetic reasoning and 7.73 in computation, both measures from the New Stanford Achievement Test; the corresponding three-year averages without home study were 7.10 and 8.03.

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CHAPTER V

Teaching of Mathematics in Grades VII, VIII, and IX

FOSTER E. GROSSNICKLE

The Curriculum for Grades VII–IX

TWO COMPREHENSIVE OUTLINES of the work for Grades VII, VIII, and IX were given in the Fifteenth Yearbook (45). The work for Grades VII and VIII is predominantly arithmetic. The work in the ninth grade in one curriculum plan is general mathematics with emphasis on the social applications of number. In the other plan the core of the curriculum is algebra, with material from arithmetic, graphic representation, and trigonometry. McCamey (36) analyzed fifty-three city and state courses of study published since 1929 to determine the type of mathematics offered in the ninth grade. She found that two-thirds of the courses were conventional and one-third "reorganized" mathematics; nine cases were both types. Half of the courses gave general objectives but did not tell how these objectives were obtained. In general, ninth-grade mathematics was predominantly algebra. Even in reorganized courses, more algebra was taught than all of the other subjects combined.

Turner (59) sought to ascertain by means of a questionnaire (a) what factors affect pupils' liking for mathematics; (b) what types of mathematics are of most value for carrying on different activities; and (c) how time allotments for various topics compare with the use and value of those topics in the lives of the pupils. Turner concluded that much of the subjectmatter of the eighth-grade course in mathematics is beyond the understanding of the average pupil and that it appears in the curriculum because of faith in some vague and indefinite future use.

Georges (23), Jahn (31), and Murray and Ritchie (42) set forth objectives for junior high-school mathematics. Drake (18) reported a project in teaching statistics in the ninth grade. He found that it is feasible to teach concepts of central tendency and percentiles.

Mallory (38) tested the relative difficulty of certain topics in mathematics for the slow-moving pupil at the ninth-grade level. The topics included in the curriculum which he constructed were selected not with a view to satisfactory pupil achievement but simply to determine which types of work most interested the pupils, and which algebra and intuitive geometry types they could do most successfully. In general he found that pupils with low IQ's were deficient in arithmetic computation. Low IQ did not prove a handicap in most intuitive geometry but it was a handicap in situations which called for more precise reasoning and generalization. Simple equations and signed numbers were easily learned in algebra, but making and evaluating formulas and using general numbers

in fundamental operations were learned with more difficulty. He found that his experimental subjects did not like and could not succeed with demonstrative geometry in the ninth grade.

Leete (35) selected basic principles governing the operations of fractions so as to avoid many of the most common pupil errors. She noted the parallel between arithmetic and algebraic computation for fractions. Short (53) showed how to correlate arithmetic and algebra, and Murtaugh (43) showed how to make factoring meaningful in algebra by calling attention to its applications in arithmetic.

Denominate numbers—Washburne (62) reported for the Committee of Seven the grade placement for teaching certain measures. The placement was determined by finding the mental age at which 75 percent of the class retained the subject with 80 percent accuracy. He found that it is not until a pupil reaches a mental age of approximately fourteen years that the fundamental operations may be performed effectively on denominate numbers.

Approximate Computation

Boyer (6) gave rules governing the operation of approximate computation. Solomon (55) took issue with conventional rules and set up his own principles. Bakst (2) gave the mathematical theory underlying this phase of number. Shuster (54) showed how approximate numbers have practical usage in connection with operations on a slide rule. West and Shuster (64) stated the conventional rules for operating with approximate numbers and concluded that such operations should be taught in the elementary school (upper grades) because (a) they are the only "real life" computation for practical purposes; (b) they give a definite criterion for rounding off numbers and for determining how far to carry out a problem in division, an equation, or square root; (c) they eliminate ragged decimals in addition and subtraction; (d) they prepare a pupil for approximate methods such as those with logarithms and the slide rule. A stimulating discussion of approximation was found in the Report of the Committee on the Function of Mathematics in General Education (48).

Achievement in Arithmetic

How does the arithmetic achievement of pupils today compare with that of a generation ago? Boss (5) investigated this question by comparing pupil achievement on a survey test in arithmetic in St. Louis in 1938 with results from the same test in 1916. The median scores for the 1916 group were higher than the median scores for the pupils of today. The author thought the difference to be due to shifting of topics in grades and to the increased holding power of today's schools. In the earlier period, many failing pupils were eliminated before the eighth grade. Grossnickle (24)

found that the achievement of ninth-grade students in division of decimals was much less than the achievement of those in Grades VII and VIII. Studying about 200 students in each grade, he found that placement of the point and not the division operation is the chief element of difficulty.

Christofferson (14) reported the results from "Every-Pupil Tests" in Ohio for Grades VII and VIII. On the whole, achievement in computational skill was found satisfactory. Ability to solve problems as revealed by these tests seemed different. The writer concluded that students come to junior high school inadequate in ability to think through quantitative situations, and they leave at the end of the eighth or ninth grade deficient in ability to utilize their skills in solving problems.

Thompson (58) reported diagnostic testing over a period of three years, of 38 students in Grades VII, VIII, and IX, and concluded that diagnosis and remedial instruction are effective. Braverman (7) tested 460 students in the ninth year to see the effect of algebra on their arithmetic scores. In most cases the arithmetic scores were improved, though the difference in means was not statistically significant.

Factors Affecting Achievement in Algebra

Lahey (33) studied a group of 229 ninth-grade students to determine (a) the amount of algebra retained after a year of studying geometry; (b) differences in retention of algebraic computation ability and problem-solving ability; (c) the effect of intelligence on this difference; and (d) sex differences in retention. The results showed (a) loss of about 20 percent during the first eight months, with little further loss; (b) a 10 percent gain in problem-solving ability; (c) a positive but low correlation between IQ and retention in fundamentals; and (d) no statistically significant difference between the average scores of the two sexes.

Effect of vocabulary and reading ability—In a matched group experiment Drake (19) found that teaching the vocabulary of algebra appreciably increased the student's achievement in the subject. Buckingham (11) found a statistically significant correlation between total scores in vocabulary and total scores in algebra.

Stright (57) investigated the effect that specific training in reading and efficient methods of study had upon ninth-grade students' reading ability and skill in solving problems in algebra. The parallel group method of experimentation was used. In reading and in problem solving, there was a statistically significant difference between the means for the experimental group and for the control group. The writer concluded that a better knowledge of reading mechanics increases a student's reading comprehension and affects his ability to solve algebraic problems. Clark (15) found that intensive training in reading resulted in a gain in algebraic achievement. Buckingham (10) found positive correlations between algebraic achievement and various types of reading scores, most of them below .40.

Measurement and Prediction

Hastings (27) made a test to measure mathematical concepts in the junior high school. He used six different testing devices. He concluded that no single technic or testing device, such as a multiple-choice test, is a sufficient index of the behaviors measured by all the other types of tests. On the basis of his finding, he drew up a concrete plan for testing mathematical concepts. Seder (52) made an objective test which contained some arithmetic, simple algebra, and elementary geometry to measure a pupil's achievement in a reorganized course in mathematics in Grades VII, VIII, and IX. There are three forms of the test, each containing 130 multiple-choice items requiring 80 minutes working time.

Prognosis—From the records of 214 eighth- and ninth-grade students, Clifton (16) formed a prediction equation from scores on the New Stanford Achievement Test, chronological age, and mental age. He was able to predict the mean grade for a class with considerable accuracy but not an individual grade. Dunn (21) tested 223 boys and girls in junior high school in ninth-grade algebra. Each pupil was given two standardized tests in arithmetic, two in algebra, and one for mental ability. A careful statistical study seemed to indicate that the teacher factor is influential in determining the correlation between achievement in algebra and the various predictive criteria taken separately and in combinations.

Seagow (51) studied 121 pupils in the seventh, eighth, and ninth grades, and found that either the Orleans Prognosis Test in Algebra or an arithmetic achievement test would yield a better prognosis of algebra accomplishment than an intelligence test would. He noted that the total test picture modified by subjective estimates of personal factors in the pupil affords a better indication of success than does any single test alone. Layton (34) found that eighth-grade mathematics marks gave a better basis for prognosis than did any other one factor that he studied.

Mathematics Equipment, Textbooks, and Other Instructional Aids

Many kinds of instruments and other pieces of equipment for the modern mathematics classroom are listed in the Fifteenth Yearbook (44). Bedford (3) drew up a list of about 150 articles for equipping a classroom to teach arithmetic through the first eight grades. Woodring and Sanford (65) also suggested certain types of equipment for the mathematics classroom and gave the places where they might be purchased. Ullsvik (60) gave a detailed list of new materials and equipment for teaching arithmetic, and of research periodicals and other publications dealing with teaching mathematics and with visual aids. Starr (56) gave a helpful bibliography of textbooks and materials for enriching a course in algebra. Mahachek (37) showed how certain pieces of equipment may be used in the mathematics classroom. Garner (22) described a score card to use for selecting a mathematics textbook at the junior high-school level. Hildebrandt (30)

cataloged a list of films available for vitalizing the teaching of mathematics. Russell (49) illustrated how pictures may be used to teach mathematical concepts.

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CHAPTER VI

Teaching of Science in Senior High School and Junior College

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SINCE TEACHER EDUCATION and historical studies are dealt with elsewhere, the subjects included here may be assigned to two general categories: (a) those relating primarily to the curriculum, and (b) those having to do with the learning process. A number of investigations sought to determine the status quo with respect to courses taught, pupil enrolments, equipment, and similar matters. Attention was also given to the selection of new content for courses, especially in the area of conservation education. New courses such as senior science and survey courses were analyzed. In the area of evaluation, the tendency to go beyond factual information in measuring outcomes was evident. Changes in attitude, in overt behavior, and in understanding were emphasized.

Offerings in Science

An extensive questionnaire study was made by Riddle, Fitzpatrick, Glass, Gruenberg, Miller, and Sinnott (56) in an effort to reveal the extent and nature of the biology program in secondary schools. Questionnaires were filled in by 3,186 biology teachers, representing all areas of the United States. It is admitted that the responding group probably was selected to some extent, and that the data therefore indicate a situation somewhat better than the one that actually exists. Findings of special interest were:

1. Biology teachers often teach other subjects, which are usually in the field of science. Nonscience subjects most frequently taught were history, English, and agriculture.

2. Teachers who also gave instructions in general science estimated the amount of biological subjectmatter contained therein to range from 20 percent to 30 percent.

3. A national average of 28 pupils per biology class and an average pupil load (per teacher) of 124 were reported. In cities of more than 100,000 population, more than half of the biology classes contained more than 35 pupils. The pupil load per teacher was also higher in large cities than in rural areas.

4. Equipment and conditions under which teachers work are not very satisfactory. This is particularly true in town and rural districts; rural schools of the South and of New England reported relatively poor equipment and facilities.

5. Promotion of biology teachers is largely influenced by success in teaching and length of service. Politics, prejudice, and favoritism were reported to play but a minor role.

6. The amount of biological instruction varies greatly in different parts of the country. Substitution of social studies for biology was reported as a recent event in about 10 percent of schools, the larger cities leading this movement. Hygiene courses had been transferred to physical education in about 20 percent of the schools. There was consid-

erable indication that many teachers presented biology as the learning of engaging hobbies, or as an aggregate of practical technologies.

7. About half of the teachers indicated that they taught the principle of organic evolution. Most of the teachers testified that they dealt with the genetic inequality of men, although in the case of parochial schools the percentage of such teachers was only 65.

Hunter and Spore (29) conducted a survey of secondary-school science offerings and enrolments, based partially upon questionnaire returns from some 665 schools and partially upon data from governmental sources. Weckstein (74) surveyed laboratory work in elementary biology, with special attention to objectives and learning experiences. Woodruff (78) analyzed the mathematics used in biology. Gerber (22) investigated the relative emphasis placed on science and social studies in secondary schools of Tennessee. The study gives further evidence that this balance is a matter of some concern to science educators. Loraine Hunter (30) reported on important biological problems of the southeastern region in relation to textbooks used and the extent to which these problems were actually considered. Kessler (36) analyzed thirty-five "popular" science books as to readability, difficulty, and general acceptability for use by tenth-grade biology pupils.

Reports on courses, personnel, and equipment of various high schools offering courses in chemistry and physics indicate that there is much room for improvement. Leach (42) made such a study for Pennsylvania, Chandler (12) for the colored schools of South Carolina, and Sister Gertrude Jose Smith (64) for the Catholic secondary schools of northern New Jersey. More analyses of similar nature might well be of value in the establishment of acceptable standards and in suggesting changes in curriculums.

Survey Courses in Science

It is evident from various reports that general courses in physical science are being offered with increased frequency, both in high schools and in colleges. Watson (71) reported this trend to be especially well marked in California, where 28 percent of the high schools offer such courses, as compared with 21 percent for cities in the country as a whole. About 28 percent of the undergraduate colleges of the country offer survey courses that deal with materials of the physical sciences. The basic question of whether the physical science survey course is more effective than the courses in physics and chemistry which it replaces was explored at the high-school level by Rosenlof and Wise (57), using 283 pupils paired on the bases of psychological examination scores, the Noll test of scientific attitude, and a devised informational test in physical science. The students in the survey course appeared to know more facts at the end of the year than did comparable pupils enrolled in chemistry or physics. Ferguson (18) explored two related questions: (a) the nature of general science

courses in the senior high school, and (b) how students of such courses compared with pupils of physics, chemistry, and biology on science tests. Clearly, more studies are needed in this area: specifically, we must be sure that all tests used are valid in terms of the objectives they purport to measure.

Meanwhile, evidence as to the effectiveness of survey courses in relation to retention was obtained by Freud and Cheronis (20) by readministering, a year later, the comprehensive test taken at the end of the course. The results corroborated earlier studies. Principles, theories, and applications were remembered somewhat better than were unrelated facts. Brewer (7) studied factors affecting achievement in a physical science survey course, and found that on the basis of final informational tests, students could be classified in significantly different groupings. These differed markedly from groupings based upon initial information, high-school preparation in science and mathematics, and intelligence. The effectiveness of a course in human biology for two quarters in preparing college students for courses in biochemistry, bacteriology, food preparation, and nutrition was compared with that of a course in zoology followed by a course in physiology, in a group of studies by Clara M. Brown (8). Studying the achievement of more than a thousand students, she concluded that comparable students with different backgrounds in science do not differ significantly in course achievement. This conclusion is in harmony with that of the Eight-Year Study (11), that the pattern of courses studied in high school is less useful for advising college entrance than is the pattern of abilities of the student.

Content of Science Courses

Wise (77) culled 252 science principles from earlier analyses and then set up criteria for selecting from eleven textbooks applications relevant to the principles. For 246 principles he found 3,153 applications. Gillson (23), as a basis for a chemistry course suited to pupil needs, analyzed letters written by former pupils, essay contest papers, questions sent to the Good Housekeeping Question Box, and returns to a questionnaire based upon the objectives of popular books and textbooks, and responded to by 400 laymen and 256 former students. She recommended differentiation of subjectmatter on the basis of sex, especially during the work of the second term, and a greater effort to teach chemistry in such a way that it will function in the lives of pupils. Showalter (62) found that diaries kept for three weeks by sixty-two adults in various walks of life indicated activities more relevant to some of the 183 chemical principles studied than to others.

P. G. Johnson (33) obtained the judgments of 240 science teachers (rural, elementary, and junior and senior high school), science supervisors, and leaders in science education with regard to course of study

materials. Testimony indicated that a looseleaf form, capable of being added to from time to time, was desired. Teachers indicated preference for separate organization of science subjectmatter based upon pupil needs and interests, divided into grade levels, emphasizing principles rather than facts, and including pupil activities and an annotated bibliography. Rural teachers favored an interchange of courses of study devised by teachers; supervisors and leaders in science education preferred a state course of study, possibly formulated with the cooperation of teachers.

Under the direction of S. R. Powers, the Bureau of Educational Research in Science (48) has defined major problems and has issued publications dealing with the impact of science on these problems. The areas in which source books especially useful to teachers are available include: national and world resources and problems of production (21); the community as an ecological unit (61); the control of organisms (19); genetic differences among people (24); and consumer education (9). Selected experiences of teachers who have dealt with these areas are reported in a series of "Suggestions for Teaching" (40, 41, 67). Several studies of changes in boys and girls whose learning has been related to these problem areas have been made in connection with the work of the Bureau (5, 43).

Conservation Education

Vessel (69) surveyed conservation education in rural areas; Quaintance (50) studied conservation education in schools and colleges. Capps (10) made a survey of the conservation information possessed by pupils in Missouri high schools. Webb (73) made an investigation dealing specifically with soil conservation, and one phase thereof represents a technic for determining relative emphasis that should presumably be given to different topics or understandings in selecting curriculum materials. The approach was to make a reading word list representative of soil conservation literature in popular books, magazine articles, bulletins, and newspapers. A survey of the possibilities of conservation education was published under the editorship of Ward (69). While not a report of research, this volume is no doubt destined to have desirable influence in modifying current programs of instruction. Kurtz (38), attempted to analyze the science information of farmers and prospective farmers in a Pennsylvania area. Most of the misconceptions held by these farmers proved to be of a technical nature.

Pupil Interests in Science

Among the more comprehensive and significant studies of interests were those made by Zim (79, 80, 81), who reported the use of various technics in an effort to ascertain the science interests of more than 3,200 high-school pupils. One approach was a questionnaire procedure in which subjects were asked what they would "like to find out best in science."

There was also a study of pupil responses to nine science exhibits. Another technic was represented by pupil expression of preference for films in a special fictitious list. In a further analysis pupils were asked to indicate science questions they had wondered about, using a prepared list as a basis. Exhibits submitted by junior high-school pupils to the Science and Engineering Fairs of the American Institute were also taken into account. In summarizing the data from such sources Zim (81) concluded, among other things, that "boys and girls show distinct differences in their interests and activities in biology," that such interests tend to be specific, and that they persist long enough to be of educational significance.

Administration of College Science Courses

Prerequisites—Wetzel (75) sent a questionnaire to chemistry professors in thirty-eight colleges. He found that one-third of the professors preferred students who have had high-school chemistry, and that 61 percent of the colleges offered separate courses for students having a background of high-school chemistry. Oakley (46) found that final test scores and final grades made by 89 freshman chemistry students who had taken high-school chemistry were superior to those of 89 paired students who had not had chemistry in high school. The analysis of scores on the Cooperative Physics Test for College Students made for the American Association of Physics Teachers showed that students with a high-school physics background were superior to the rest of the group both at the beginning of a course and at its conclusion. The scores also indicated that students who enrolled in courses having prerequisites showed no superiority over students in courses which had no prerequisites.

Speed-up of college programs—Administrators pondering the advisability of speeding up the teaching process in college science courses will be interested in Oakley's finding (46) that seventy-two college freshman chemistry students using a rapid, theoretical approach, showed superiority over matched students in a standard course. Clark (13) paired thirty-two students in an advanced freshman chemistry course with students who had also had high-school chemistry but were enrolled in an elementary chemistry course. In fourteen weeks the advanced course group gained as much as the others did in a semester. The report concerned with the use of the Cooperative Physics Test for College Students during the past six years showed that courses requiring more lecture and recitation time do not result in superior achievement; neither do courses carrying an unusually large number of credit points.

Outcomes: Attitudes, Critical Thinking, Misconceptions

The recognition of objectives in science teaching other than the acquisition of information, as represented in the period of the preceding review by Noll in the field of attitudes and Tyler in the area of critical thinking.

has continued. DeWitt (15) used data from the "Youth Expressionnaire" of the Character Education Institute to study differences in attitudes among three groups. One, composed of fifty college graduates who had studied science, had greater respect for accuracy, was more open-minded, was international-minded, and liberal from the religious standpoint. A comparable group of college graduates who had not studied science, however, was found to be no more superstitious. On the other hand, one hundred high-school graduates of comparable age proved to be relatively superstitious and conservative.

The Eight-Year Study (1) employed specially devised tests (63) such as "The Application of Principles of Science," "The Nature of Proof," and "The Interpretation of Data," to select the students recommended to colleges. The 1,475 students accepted from the "thirty schools" cooperating were matched with the graduates of other schools as to sex, age, race, scholastic aptitude scores, home and community background, interests, and probable future. The students from the "thirty schools" (especially those from the least traditional schools and those graduated recently after programs were improved), excelled in college physical sciences, and it is reported that they surpassed the control group in intellectual curiosity and in scientific approach to problems. The graduates of the "thirty schools" were judged to be precise, systematic, and objective in their thinking; they demonstrated a high degree of resourcefulness in meeting new situations, and managed to earn a higher percentage of nonacademic honors.

Ralya and Ralya (53) tested 325 college freshmen with an instrument devised from fifty-two correct and erroneous geological and astronomical concepts. They found that the prevalence of one misconception was no criterion as to the prevalence of a related misconception, and that freedom from misconception was positively correlated with scholastic aptitude. Ralya and Ralya (52) used a Science Inventory of 232 items to test 325 college freshmen, and reported results on eighty-two items in biology and anthropology which were selected to represent (a) common unfounded beliefs, and (b) important concepts and principles. Among the findings was evidence that many persons believed in spontaneous generation, that 70 percent were unaware that "human beings begin their lives as fertilized eggs," that many believe in the inheritance of acquired characters, and that 14 percent accept strong coffee as a remedy for malaria. The results again indicated that the high scholastic aptitude group fared better, and sometimes much better, than the low scholastic aptitude group.

Using 364 eleventh- and twelfth-grade pupils as subjects, Meder (43) found that groups studying a pamphlet about the physical universe gained more information than did pupils in discussion groups or control groups and shifted their opinions further from the concept that man is dominated by supernatural forces. The correlation between shift in opinion and score on an intelligence test was also significant. Brewer (7), who used both

"attitude" and "thinking" tests in his study of a college physical science survey group, detected some shifts in attitude during the semester. Salt (58) investigated erroneous ideas about health, using 3,221 pupils in thirty-two schools as subjects. Findings indicated a prevalence of unfounded beliefs, especially about advertised products and physical activity.

Nature of Learning; Understanding Applications

When physics teachers in twenty-four Wisconsin towns of less than 30,000 population gave their pupils tests based upon an analysis of textbooks, Ralya (51) found that pupils sometimes knew facts but not the principles involved; knew metric and English units, but not how to convert them; could recall formulas and figure out the answers to problems, but did not understand the principles involved. Sometimes pupils who were able to apply a principle in one situation did not see its application to other situations. Schindler (59) found that among 300 physics pupils in thirty-four Iowa schools, 70 percent memorized satisfactorily but only 17 percent really understood. Low-ability pupils in particular did better on items of simple recall type than they did on items which seemed to necessitate somewhat more understanding.

With 120 pupils of high-school physics paired as to teacher, previous science courses studied, and IQ, Kilgore (37) learned that both low- and high-ability pupils were significantly better in making application of principles when their course had emphasized applications. Similarly, Babitz and Keys (2) matched eight chemistry classes in two California high schools. Control groups followed standard methods of instruction, while experimental groups had more "direct and intensive instruction" on the application of principles. Tests required that the pupils solve chemistry problems and also be able to identify scientific principles related thereto. On post-tests all experimental groups showed superiority over control groups of the same school, although the differences were not statistically significant.

Huebner (28), Schwachtgen (60), and others studying with W. L. Beauchamp found that pupils who answered a series of study questions concerning laboratory work had better test scores than did those pupils who wrote formal reports on laboratory experiences. Steuber's study (66) of four physics classes suggests that a qualitative approach may be more efficacious than a quantitative one. On a test composed of both qualitative and quantitative problems there was no significant difference between students who had experienced only qualitative work and those who had solved quantitative problems. Mudge (45) reported that matched groups gained significantly during a chemistry course both with respect to knowledge and the ability to apply knowledge; the informational gain, however, was the larger. Her results showed no significant difference between high-school and college groups in ability to apply chemical knowledge.

Interest was also shown in the results of various methods used to teach college biology. Stevenson (65) reported upon the relative effectiveness of three types of instruction in a normal school. Kahn (35) compared the laboratory method with a demonstration method of teaching biology in colleges. Brown (8) in an extended investigation found that certain biological concepts and the ability to make interpretations in the light of them are taught as satisfactorily in nonlaboratory courses as in laboratory ones. According to Barnard (3), who was working with college students enrolled in two introductory courses in biology, the lecture-demonstration is better with respect to specific information, but the problem-solving method is superior with respect to problem-solving ability and the formation of attitudes.

Microprojection—Edith Brechbill (6) was interested in the microprojector as a teaching aid. She compared the learning of 550 paired (IQ and MA), biology pupils taught by two different teachers in two senior high schools. The experimental groups used microprojection and the control groups employed the older microscope technic. Four objective, standardized tests to "measure learnings from microscopic material observed" served as pre-tests and post-tests. In two experimental groups the gain was greater than in corresponding control groups, but in two other cases this result was reversed. In no case, however, was the difference statistically significant.

Changes in Behavior Following Science Study

One of the most challenging learning studies made in the five-year period was that of Bingham (4), who analyzed the effects of instruction (food and nutrition) upon high-school pupils. Bingham employed the usual tests and controls, but in addition he was able to get reasonably objective data concerning modifications in overt behavior subsequent to instruction. The Bond study (5) was of the more traditional type but introduced a new element in that it attempted to relate teaching of genetics to the objectives of general education. Bond's emphasis was upon change in information and opinion subsequent to instruction. Waters (70) analyzed pupil and group diaries, written work of pupils, anecdotal records of both the teacher and other observers, and pupil evaluations of their work in science, in order to study changes in pupil behavior.

Heil (25) reported the use of "inventories" to evaluate the effectiveness of science teaching (general courses) in eighteen colleges participating in a cooperative general education study. Specific items were "suggested in a large part by other investigations and agencies," or were contributed by "the individual college instructors and members of the central staff of the study." These items were then assigned to inventories in the case of health (the example cited). The student was asked to indicate the relative frequency with which he engaged in good and bad health practices for

each inventory. It is to be noted that while this technic gets at the testimony of the students, it does not measure actual overt behavior.

Prediction of Success in Science Courses

Clark and Rice (13) carried out an interesting study of 557 students in five science departments of Muskingum College. The estimates made by these students as to their marks were the same or higher than the marks actually received more than 75 percent of the time. The correlation coefficient between the estimates of all students and that of the professor concerned was .66; the comparable figure for mathematics students was .81. DeWitt (15) reported that college graduates who studied science, graduates who did not study science, and high-school graduates of an age similar to the others were equally able in estimating their own abilities.

Peterson (47) studied the relationship of certain tests and other items to predicting success in high-school biology. Dickter (16) studied the relationship between scholastic aptitude test scores and college grades in mathematics and science. Oakley (46) found intelligence test score and the rank in high-school class equally good criteria for predicting achievement in college freshman chemistry. Mercer (44) worked out a regression equation for success prediction in engineering curriculums on the basis of general mental alertness, mental multiplication of spatial relations, verbal academic response, and analytic reasoning. The Educational Records Bureau (39) has made available separate norms on the Cooperative Physics Test for College Students for typical students of college physics, for women students (scores are lower), and for engineering students (scores are higher). The responses of college sophomores to the Cooperative General Science Test were studied by Howard (27), who identified a high amount of a "science" factor and a low amount of a "complexity" factor within the test.

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CHAPTER VII

Teaching of Mathematics in Senior High School and Junior College

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Geometry and the Development of Logical Thinking

SEVERAL INVESTIGATORS have considered problems centering about the teaching of logical or "critical" thinking. Lazar (16) made an analytical and historical study of the terms "converse," "inverse," and "contrapositive" in geometry and their applications in textbooks. He formulated new definitions of these concepts and illustrated them with propositions from plane geometry. Smith (26) published data obtained in 1932 on errors made on a series of diagnostic tests by a group of 114 pupils having a mean IQ (Terman) of 118. He noted the extent to which, under ordinary conditions, students fail to comprehend the "if-then relationship" and the meaning of proof. He also showed how slight changes in the details and complexity of construction exercises increase the number of errors made by pupils. In 1939, with a group of 74 pupils so selected that the mean and the standard deviation of IQ's were the same as those of the 1932 group, the procedure was repeated except that methods of teaching were designed especially to emphasize and facilitate analysis and generalization by the pupils. A comparison of error counts revealed statistically significant reductions. This investigation provided data on the extent to which transfer fails to take place even within a narrow field unless it is facilitated by appropriate instructional methods.

Fawcett (9) sought to develop general concepts and abilities related to proof. He emphasized the necessity for clearly defined terms, for assumptions or unproved propositions, and for realizing that no demonstration proves anything beyond the limits set by the assumptions. The majority of his experimental group of 25 pupils was in the eleventh grade, having a median IQ (Otis) of 115. These students were given a course in which the primary features were (a) the development of geometric concepts and principles by individuals and by group discussion, without the aid of a textbook, and with unusual emphasis upon a creative type of logical thinking; and (b) the utilization of nongeometric reasoning situations for introducing, clarifying, and applying logical concepts and abilities. The organization and content of the course accordingly departed markedly from the traditional. Test results indicated that the pupils made a statistically significant gain in the ability to analyze nonmathematical material, while pupils in several other groups used for comparison did not. Fawcett recorded numerous instances of "transfer of training" apart from his tests. Although achievement of geometric knowledge was not the major objective, the median score made by the experimental group

on the Ohio Every Pupil Test in plane geometry fell between the 80 and 90 percentiles of the state scores. This study was not rigorously controlled, and the experimental group was small and probably unrepresentative, but the report has exerted considerable influence on instruction in geometry and has stimulated other investigations.

A study by Ulmer (28) extended Fawcett's results by making use of a control group of students taking an ordinary course in plane geometry and of a second control group of students who did not take geometry. These groups and the experimental group were each composed of 330 students so selected that the mean and standard deviation of the ages, the intelligence quotients, and the scores on an initial reasoning test were approximately the same. The classes in the experimental group were taught by ten teachers in six different schools. The classes in the geometry control group were taught by eight teachers in six different schools. The data indicate that the procedures used with the experimental group (primarily emphasis upon the application of principles of logic to non-geometrical situations) produced marked gains in the abilities measured by the reasoning tests. There was no measurable gain for the no-geometry control group and a slight gain for the geometry control group. The study ran for one semester only, and no measures of achievement in plane geometry were obtained. The experimental teachers reported, however, that there appeared to be no loss in achievement, and some indication of gain as judged by their regular tests. Ulmer also separated the data for each of the groups into subgroups having low, average, and high intelligence test scores and showed by the distribution of the mean gains that pupils at each intelligence quotient level are capable of profiting from special instruction in principles of logical reasoning. This study confirmed the results of numerous former studies to the effect that little transfer takes place unless special procedures are adopted to facilitate it. It extended Fawcett's results by showing that high-school geometry teachers, under normal classroom conditions, can teach in such a way as to develop the ability to apply principles of logical reasoning to non-geometric situations.

Essentially the same conclusions were drawn by Gadske (10) in a similar but unusually comprehensive study of the same problem. Six teachers in three public high schools taught 333 students in the experimental group. A control group of approximately the same size in three similar schools had a mean intelligence quotient (Otis) which exceeded that of the experimental group. This superiority together with the fact that the students in the control group devoted all of their time to geometry doubtless explains why the geometric achievement of the control group at the end of the study was superior. On a reasoning test, however, given to both experimental and control groups at the end of the experimental period, a significantly higher mean score was made by the experimental group. Questionnaires exploring the point of view of students toward

mathematics showed marked shifts in the experimental group between the beginning and end of the course in choice of mathematics as a favorite subject, in point of view toward values of mathematics, in concepts of critical thinking, in the number of books and articles read in connection with the course, and the like. These data, plus results of a nongeometric reasoning test and extensive observational records, support the hypothesis that the experimental group changed more than the control group in an educationally desirable direction.

Although these studies provide impressive evidence that the ability of students to handle nongeometric reasoning situations may be improved through appropriate procedures in geometry courses, the differential contributions of the geometric and nongeometric content have not been isolated.

Prediction of Success in Mathematics Courses

In the REVIEW OF EDUCATIONAL RESEARCH for February 1938, Douglass and Kinney observed that investigations aiming to forecast the probable success of students in mathematics courses were relatively numerous. This tendency has continued during the period covered by the present review but there has been no fundamental modification of previous findings.

Clifton (5) reported multiple coefficients of correlation of approximately .57 or lower between teachers' marks quantified on a five-point system and various other measures. Data were collected for 214 ninth-grade students during the years 1931-1936. The coefficient obtained by using for prediction both scores on the New Stanford Arithmetic Reasoning Test and the intelligence quotient was .57 and the inclusion of other variables including reading scores did not increase it appreciably. Seagoe (24) studied the relationship between scores ($N = 121$) on the Orleans Algebra Prognosis Test and other measures. She reported correlation coefficients between the Orleans test and three intelligence tests, namely, the Terman group test (given just prior to high-school entrance), the Otis Intermediate Examination, and the Kulmann-Anderson test (given two years later), of .63, .67, and .74, respectively. From these and other data she concluded that an algebra prognosis test, or better, the New Stanford Arithmetic Tests, would yield more reliable data for prediction than any intelligence test.

Layton (15) reported a coefficient of correlation of .82 ($N = 141$) between grades in eighth-grade arithmetic and ninth-grade algebra. Multiple correlation technic using intelligence quotients (Otis) in addition to arithmetic grades yielded .84; with scores on the New Stanford Arithmetic Test and the Lee Test of Algebraic Ability added, the multiple coefficient was .86. These values are relatively high compared with those reported elsewhere.

Additional evidence that effective retention and use (or transfer) of algebraic abilities is related to intelligence was presented by Pratt (21). Among a total of 1,229 American Council on Education Psychological Examination blanks of matriculating freshmen at a teachers college, he found 550 papers which contained evidence that algebraic procedures had been used in the solution of problems in the arithmetic section of the test. The mean scores of this group on the arithmetic section and on the entire test were higher (critical ratios 13.6 and 17.2 respectively) than those of the group giving no evidence of the use of algebraic thinking, and the superiority was not solely ascribable to the higher scores on the arithmetic section.

The prediction of success in college courses by means of correlation studies continues to attract investigators. Thus Dickter (6) computed coefficients of correlation between scores on the mathematics section (which, from 1930 to 1936, was a part of Scholastic Aptitude Test of the College Entrance Examination Board), and marks in five different mathematics courses at the University of Pennsylvania. He had a total of 4,423 cases, and his coefficients ranged from .40 to .60 approximately, the highest occurring when grades in college algebra were used. Since some students with low scores on the Scholastic Aptitude Test had not been admitted to the University, the range of talent was thereby restricted. Quaid (22) found that scores on the Ohio State University Psychological Examination and grades for the first semester of college mathematics correlated .561 ($N = 140$). When the second semester grades were used he obtained .855. The mathematics involved in these courses consisted of algebra, trigonometry, solid geometry, and analytic geometry. Although he also reported much higher coefficients resulting from a correction for attenuation, the value of such coefficients is doubtful since the underlying assumptions cannot be satisfied in practice. He also reported that the scores on the American Council Psychological Examination yielded coefficients of .61 and .63 with first and second semester grades respectively.

Data presented by Scott and Gill (23) indicate that the number of units of algebra taken in high school is more closely related to the grade in college algebra than the number of years that elapse between completion of the high-school and the college work. Marshall (17) gave the Columbia Research Bureau Algebra Test, the Iowa Algebra Aptitude Test, and the American Council Psychological Examination to entering college freshmen ($N = 44$). Grades in college algebra (for which he claims unusually high reliability due to the method of scoring tests used by the instructor) correlated with the algebra test scores to the extent of .79. Correlations with the aptitude and psychological examination were .56 and .49 respectively. This population is so small that generalization from it is unwarranted but the data provide some additional evidence for the long held and not unreasonable conclusion that achievement in a field is the best single index of success in subsequent courses in that field.

Kellar (13) studied the relationships among tests of algebra (four aspects), arithmetic (computation and reasoning), intelligence, reading, and memory. Scores from 284 pupils who had completed one year of algebra yielded a multiple correlation coefficient between verbal problem-solving ability in algebra and all the other variables, of about .81. Analysis of the data indicated that about 40 percent of the variance in algebra verbal problem-solving ability is due to variance in algebra computation ability and about 15 percent of the variance is due to variance in arithmetic problem-solving ability. Approximately 40 percent of the variance is due to causes not measured by the other tests, among which she suggests factors such as interest and attitude.

In summary, it may be noted that work on prediction to date suggests the hypothesis that a reliable index of the success of individual students in algebra is not likely to be found until methods are devised which reduce or eliminate the most probable sources of variability in previous investigations, namely, the known unreliability of teachers' marks and the influence of pupils' interests, work habits, and similar factors. Moreover, it seems likely that no widely applicable formula will be forthcoming, and that each school and college must study its own population.

Reading and Vocabulary Studies

Kellar's study referred to above provided data on the relationship between reading and the various factors she studied. The coefficients of correlation were positive but less than .51 except in the case of the tests of algebraic vocabulary and intelligence which yielded .56 and .76 respectively. McKim (18) constructed tests especially designed to measure reading of algebraic materials. These were administered to a group of 120 students for which the mean IQ (Terman) was 117. These students were, however, given no special instruction in reading algebraic materials and were taught by a method in which new work was presented almost entirely at the blackboard. The correlations of scores on the four parts of the McKim reading tests and intelligence quotients did not exceed .56 and the correlations with the scores on the midterm and final examinations did not exceed .62.

Stright (27) also studied the relationship of reading comprehension to skill in solving algebraic problems. One group ($N = 29$) of students spent one hour a week studying the "Student's Guide to Efficient Reading" by Pressey, and in reading books and magazines. They were also given special help in reading as needed. A control group ($N = 33$) comparable on the basis of the Iowa Silent Reading Test and the Henman-Nelson Test of Mental Ability was not given this training. At the end of the school year the differences in the mean scores of the two groups on a second administration of the reading test and on the Cooperative Algebra Test were favorable to the experimental group and were statistically significant. A similar study by Clark (4) also points to the same conclusion.

The effect of special emphasis in teaching upon the vocabulary of elementary algebra was studied by Drake (7). Experimental and control groups, containing pairs of students matched on the basis of both intelligence and algebra achievement tests, were secured in six different schools. Vocabulary tests for seven units were constructed using a multiple-choice technic requiring the student to associate a word with an example. During the unit, remedial instruction averaging about 7.5 minutes per class period was given the experimental groups. Results for five units and for the final algebra test were reported for combined groups from several schools (usually including 100 or more students) and showed significant differences favoring the experimental group.

Curriculum and Methods in Geometry

Brownman (3) compared two methods of teaching geometry as an experimental science in an industrial high school. He used experimental and control groups each composed of fifty students matched individually as to intelligence quotient and scores on a geometry inventory test. The control group was taught by the lecture-demonstration method, and the experimental group by the individual-laboratory method. On the basis of final test scores he found the latter method superior, particularly with respect to the acquisition of descriptive and experimental concepts. With respect to skills, applications, and the ability to solve "integrated problems," differences in the mean scores of the two groups were in favor of the experimental group but were not in general statistically significant at the usually accepted levels. No data were reported on the reliability of the tests used.

Using sets of exercises in geometry graded according to three levels of difficulty, Lane (14) investigated the effects of allowing pupils to select for proof a smaller number of more difficult originals in contrast with the more usual procedure. Ten teachers in nine high schools participated in the experiment. Experimental ($N = 174$) and control ($N = 163$) groups were equated on the basis of the means and standard deviations of the Orleans Geometry Prognosis Test and the Otis Higher Examination. Lane found that average scores on the final tests favored the experimental group by amounts which were not statistically significant. The plan of pupil selection of graded originals seemed to have some slight advantage for boys and was most suitable for pupils of high ability.

Pickett (21) analyzed 150 geometry examinations given during the period 1923-1935 among College Entrance Board Examinations, the New York Regents' Examinations, the Annapolis and West Point Entrance Examinations, and selected state examinations. He rated geometric theorems in terms of their utility in proofs and exercises demanded in the examinations, and found that sixteen theorems are sufficient to supply 50 percent of the reasons used in proofs. He prepared a "Persistent List of Theorems" and revised the list of the National Committee on Mathe-

matical Requirements, reducing the number of theorems from 89 to 58. He found that a major portion of the test items could be solved by the analytic method of proof but that the indirect method was seldom required on the examinations he studied. He also provided tabulations showing the relative importance of algebraic abilities, the relative frequency of theorems, definitions, constructions, postulates, and axioms used in proofs, and he reported that 36 percent of the exercises were applied problems calling for a numerical answer or algebraic treatment.

Teaching Slide Rule Computation

Problems encountered in teaching students to use the slide rule were studied by Shuster (25). He recommended that the fundamental concepts of approximate computation be taught first, and that the use of the slide rule should not be introduced before the middle of Grade IX on the ground that the location of the decimal point by expressing numbers in standard form cannot be efficiently taught earlier. He found that early instruction should be limited to one- and two-digit accuracy, and that considerable drill on reading the third significant digit and on examples involving zero as a significant digit is desirable. Errors in slide rule computation made by an experimental group of 150 college students were greatly reduced when special teaching technics based on these findings were employed. Moreover, students who had learned to use the slide rule efficiently made fewer and less serious errors in slide rule work than in pencil-and-paper computation.

Diagnosis and Remedial Instruction

The learning difficulties of students in a course in general mathematics at the college level were studied by Boyd (2). She gave approximately 200 women in Hunter College a series of 20 ten-minute short-answer tests and analyzed in great detail the errors made by 20 percent or more of the students. She reported that the greatest single difficulty was failure to understand the question to be answered. Difficulty was also encountered in understanding the conventions of tabular presentation and in computing with simple fractions. Many students apparently did not or could not study the text. Retests at the end of each unit were used to measure improvement after ten types of remedial work. Greatest improvement came through explaining the meaning of items and symbols misunderstood on the first test, clarifying fundamental concepts, and teaching the methods of attacking and planning solutions. Relatively smaller improvement resulted from defining words unknown to some students, reviewing memory work and algebraic manipulation, and attempting to remedy faulty expression.

A series of papers by Keller, Shreve, and Remmers (11, 12) reported results from the diagnostic testing program for freshmen in Purdue

University. A battery of three tests was used to measure students' ability to perform correctly fundamental manipulative operations in arithmetic and in algebra. For each arithmetic item an index of students' inability to perform operations and the accuracy of performance was reported. In the case of the algebra tests the errors were classified and reported in terms of a code.

The effect of a carefully planned program of remedial teaching in college freshman mathematics was investigated by Wolfe (30, 31). He employed an experimental group ($N = 66$) and a control group ($N = 63$) of initially deficient students matched on the basis of (a) score on an initial mathematics test, (b) chronological age, (c) decile group on psychological test, and (d) lapse of time since completion of last preceding mathematics course. Both groups took the same trigonometry course but the experimental group was given remedial instruction outside of class averaging fourteen recitation hours. The greater part of this work was highly individual and was based upon diagnostic test results. Wolfe found that this instruction reduced the failing rate of the experimental group, and that on the original test given again at the end of the trigonometry course these students had a higher mean score (critical ratio 12.6) than the control group and were better than the originally superior total group from which they had been selected. When the same test was administered at the end of the following course (college algebra), the superiority of the experimental group remained, the critical ratio in this case being 6.8.

Mathematics in Science Courses

Dunbar (8) analyzed twelve college textbooks in general chemistry to determine (a) the number of mathematical problems contained in them; (b) the amount of space devoted to these problems; (c) the types of problems; (d) the kinds of mathematics needed for solving these problems by the simplest and most direct methods; and (e) the correlation of these findings with a previous study of twelve high-school textbooks. He found (a) wide variations in the number of problems and space allotment; (b) the most frequent problems were those dealing with reacting weight, weight and density, concentration of solution, gas volumes, chemical composition, electrochemistry, and derivation of formulas from experimental data; (c) proportion is used in the solution of three-fourths of the mathematical problems; (d) mathematical problems in college general chemistry books are similar in type to those in high-school books but are far more complex and numerous. Nickle (19) summarized the mathematical content most used in physics, chemistry, and engineering. He examined twenty-eight master's and three doctor's theses leading to a summary list of topics considered most important when judged in terms of use.

The relation between grades in secondary mathematics, physics, and chemistry was investigated by Winegardner (29). Pearson's coefficients of

correlation between grades in two mathematics courses (elementary algebra and geometry), history, physics, and chemistry ranged from .49 for elementary algebra and physics ($N = 213$) to .64 for geometry and chemistry ($N = 304$). The first of these is smaller than the coefficient for algebra and history, which was .55 ($N = 425$). Winegardner concluded that among the variables he studied geometry grades provided the best single measure for predicting success in physics and chemistry.

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CHAPTER VIII

The Teaching of Science and Mathematics in Extraschool Education

M. L. ROBERTSON

THE DIVIDING LINE between nonschool educational agencies and the school as it interacts with the whole community in its integrated program is not definite, and the selection of areas for this review is, therefore, arbitrary. Reports and studies dealing with student needs are included; so are studies dealing with certain educative agencies, namely, newspapers, magazines, and books; radio; motion pictures; and clubs.

Several listings of educational agencies outside of school are available. Rugg (53) reviewed "Non-School Educational Agencies" and gave an extensive list together with a statement of the types of education judged to result from their activities. Gruenberg (19) listed agencies more specifically related to science. Thirty-four agencies are revealed in Mathewson's study of the means of meeting professional needs. These include books, magazines, government agencies, libraries, newspapers, and the radio. His study indicated considerable dissatisfaction with present functioning of these agencies.

The need for greater utilization of extraschool opportunities has been apparent for some time. In 1924, Harap (22) mentioned the wide discrepancy between knowledge and practices of citizens and approved standards for commodities. Misconceptions still exist among citizens (21, 31). Aldrich (1) summarized research in the area and indicated a need for more consumer health education, for the removal of misleading advertising, and for increased participation by pupils in community life. That pupils are participating widely in out-of-school activities, such as helping to choose household supplies and selecting camp sites, was reported by Relyea (50) who used a loose technic in her study. Bye (8) offered an extensive list of objectives for community study. Rubin (52) suggested that the medical examinations of children and home visits by the visiting nurse should educate parents. Extraschool agencies and experiences have been used for motivational purposes more than for instructional purposes, according to a statement by Breslich (6). Heaton and Koopman (25) established, as a category important for college students, one that involves such science materials as soils, minerals, plants, animals, and ecological relationships. Understandings in such a category would clearly be dependent upon community study.

Needs To Be Met through Extraschool Activities

The reports *Mathematics in General Education* (46), *Science in General Education* (47), *The Place of Mathematics in Secondary Education* (41),

and *A Philosophy for Science Teaching* (42) suggested ways and means for providing "rich and significant experiences in the major aspects of living so directed as to promote the fullest possible realization of personal potentialities, and the most effective participation in a democratic society." The emphases in these reports were upon the needs of boys and girls, problem solving as an essential skill, and life-centered activities as a means of learning. Their stress on primary sources of learning is interesting to contrast with earlier approaches to life-activities as educational factors (26).

Studies of pupil needs, together with studies of contributions of extra-school experiences toward meeting those needs, would seem to be of great value. That vocational needs are somewhat met by mathematics was reported by Meigs (36). Her follow-up study of vocational adjustment reported student opinion that mathematics was the high-school course, outside of business courses, most valuable for making vocational adjustments satisfactorily. That certain chemical principles had more utility for adult living than did others was found by Showalter (55) from an analysis of diaries kept by adults. Although considerable attention has been given to analyses of citizens' needs for mathematics and science instruction, little objective material has been reported concerning the contribution of non-classroom life-activities toward student development, especially mental and emotional development. With well-prepared materials, Aldrich (1) illustrated technics of community utilization. The desirability of a more refined technic in surveying industries to reveal community contributions to general science was pointed out by Loudin (34).

Burnett (7) stated that extraschool education seems more functional in controversial issues, such as genetics and evolution, than does formal training in science. Its value in teaching conservation information is reported by Capps (9) who compared pupils living in rural communities with ones living elsewhere. The pupils testified that summer camps, Boy Scouts, nature clubs, newspapers, magazines, and the radio were helpful nonschool agencies. Relations between thirty-two extraclass activities and achievement in academic subjects were determined by Beauchamp (3) in a study of 900 schools and 6,500 pupils. Positive relationships between science and Scouting, collecting, and other hobbies were noted. The findings of these studies are in contrast to Downing's earlier report (16) that out-of-school experiences did not contribute to science information as then measured.

Should student needs be met through school courses or through educational experiences which include both school and out-of-school activities? Whether mathematics should be taught in a series of separate courses or as one phase of a unified educational matrix was one of the twelve issues in mathematics teaching identified by Howard (29). The National Council of Teachers of Mathematics favored relating the child's experience to his total environment, including extraschool situations. Boardman (5) main-

tained that the school and the community are jointly responsible for the development of happy, efficient, and successful adults. There seems to be a real need for studies dealing with methods of selecting and utilizing extraschool educational experiences in both science and mathematics.

Newspapers, Magazines, and Books as Sources

Since Curtis (13) pointed out that large amounts of scientific literature are read for recreation by pupils who are given access to suitable books and magazines, the potential contribution to education in science of various types of publications has been studied. Both Curtis (13) and Rice (51) reported that extensive reading of general science materials contributed materially to the scientific information possessed by pupils. Students themselves, according to Kutz (31), testified that they found newspapers helpful in keeping up with current information, for instance, about health. However, children of foreign-born parents seemed to prefer picture newspapers and motion pictures to reading material (56).

Both earlier and later investigators claimed that nonschool materials give an emphasis to science and mathematics unlike that found in school. Public health is more important in the biology found in newspapers than would be indicated by the space given to it in textbooks (28, 31). Food-producing plants are given seven times as much space in current periodicals as in textbooks (38). Analyses made of reports from Consumers' Research, Incorporated (45), *Life* magazine (15), and publications of the U. S. Biological Survey (57) revealed terms and principles not used in textbooks. In 98 government publications, Weid (57) found twelve principles of biology mentioned nearly 5,000 times. The principle, "Food, oxygen, moisture, and temperature are necessary to life," accounted for 85 percent of the mentions. That greater attention is given to biological than to physical science in published materials was evident from an early study by Searle and Ruch (54). However, analyses of periodicals and books have also been made for both chemical and mathematical concepts. Nuser (44) studied the chemistry found in agricultural periodicals and reported that the chemical processes of everyday living were emphasized. Downs (17) analyzed newspapers to determine what mathematical concepts and abbreviations were used. He found more than a thousand which were not treated in elementary mathematics textbooks. Woodruff (59) analyzed nearly 500 books and periodicals by the Braun-Blanquet quadrant method in order to determine what mathematics was essential to biology at each level of instruction. Newland (43), in a careful study of the articles and advertising of 200 issues of four popular magazines, found 2,490 allusions to science occurring in 24,022 contexts. The three most emphasized allusions were made to personal health, food, and appliances. Two percent of the allusions were found to be persistent over a ten-year period.

A similar analysis with particular reference to health claims in advertising food, drugs, and toilet supplies was completed by Edgerton (18). She identified health claims in twenty-two magazines and eight newspapers, validated the accuracy of the claims by authority, and submitted a checklist of the items to a well-chosen sample of about 800 women. She found that (a) health concepts of 50 percent of the cooperating women paralleled the claims in the advertisements, (b) invalid health claims were accepted by 50 percent of the women, (c) less agreement with invalid claims accompanied more schooling, (d) fewer invalid claims were accepted by women under twenty-five years of age than by women over twenty-five years of age. A need exists for more studies of meanings and attitudes developed through the circulation of printed materials among consumers. Attention might well be given to criteria for selection and presentation of such materials as are educational.

Radio in Science Education

Of 400 articles, theses, and books relating to radio, Miles (39) found ten which referred to the teaching of science in or out of school. Lohmeyer and Ojemann (33) reported that science material presented by talk or dramatization is learned better than that presented by discussion. The criteria of value for radio programs seem to include acquisition of information, formation of desirable attitudes, and stimulation of interest. In the Lazarsfeld study (32), children who were questioned reported the acquisition of information especially from "quiz" programs. Cohen (12) found that the radio was as effective as silent reading for having children gather information. Carpenter (10) stated, without supporting evidence, that desirable attitudes toward and interests in science could be developed through radio use. That such values might not be limited to children might be inferred from the fact that 25 percent of the parents of the 18,500 pupils also listened to the programs. Further evaluations of radio programs may be found in reports of the Federal Radio Education Committee of the Federal Communications Commission.

Motion Pictures

What are the educative values of motion pictures for the many who see them? This is an important question for those concerned with what children are learning. Nearly a third of the 70,000,000 persons in weekly attendance at motion pictures are minor children (14). Most of them view recreational films rather than scientific or documentary ones. Currently, though, hundreds of films for educational use have been selected by the Advisory Committee on the Use of Motion Pictures in Education (24). That there are informational learnings from seeing motion pictures is evidenced by many studies, from the early one by Wood and Freeman (58) to the current one by Bell (4). Gains in information and in ability

to interpret phenomena are in excess of gains through some equated means of instruction. This is especially true for older pupils who profit more from motion pictures than do younger ones, according to Bell, and to Reitze (49).

Clubs Which Foster Science

Since Meister's early study (37) in which unequated groups in a science play shop were found to acquire knowledge, constructive ability, and ability to plan, attention has been given to the educative values of clubs. During that time, clubs have increased in number. In 1939, according to Joseph (30), there were 1,500 clubs in science and engineering, including student science clubs in senior high school. Programs of the latter were analyzed by Astell (2) and were found to be mainly extensions of classwork, rather than programs of life-centered activities. One value of student science clubs was reported by Clem and Dudleston (11) who found that club members excelled nonmembers in respect to knowledge of common science. Mussey (40) found that a scholarship society stimulated scholarship in brighter pupils, although not especially so for pupils in science.

Joseph (30) developed a technic for selecting club activities. By the use of suitable criteria and the aid of expert juries, he selected from 2,385 noncurriculum activities, 185 which were thought to contribute to understanding stated principles of science. Zim (60) analyzed 815 nine-page questionnaires and reported that one-third of the boys and girls responding indicated membership in scientific clubs. Zim was primarily concerned with adolescent interests in science. He went on to report that adolescents develop science interests through visits to such places as museums and zoos; nearly half of the hobby interests of boys and girls are potential leads to science activities; sex differences are evident in relation to membership in science clubs; and science books and magazines play definite roles in adolescent science activities. Zim also analyzed 1,576 individual entries in the Children's Science Fair of the American Institute of the City of New York, together with 506 of the exhibits. He found that boys were approximately five times as active participants as were girls; and that certain science areas, as well as certain specific interests within those areas, were favored for exhibits. In a further attempt to explore the effect of science interests upon activities in and out of school, Zim studied questionnaires from 230 exhibitors. He interpreted the data to indicate that (a) help with the science exhibits was obtained from science teachers, friends, and fathers in the order named; (b) both boys and girls exhibited strong preferences for science related to health, growth, reproduction, and animal life; (c) half of the science collections exhibited were biological ones, assembled usually within three years; (d) 72 percent of the boys and 68 percent of the girls worked in science laboratories outside of school

hours; (e) 63 percent of the boys and 25 percent of the girls had a place to experiment at home.

Activities of a camp were analyzed by Hollandsworth (27). He compared them with a composite list of general science activities and found that 75 percent of the listed activities were treated at camp with parallel activities. His study had no indication that the camp program was typical.

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CHAPTER IX

Teacher Education in Science and Mathematics

R. WILL BURNETT

A DECADE AGO reports of research about the preparation of teachers of science and mathematics frequently questioned their own validity on the grounds that the goals of science and mathematics education and the responsibilities of teachers of those subjects were as yet unclear. This problem of clarification has also been the concern of a considerable proportion of research reported since 1930. Various criteria for the reorganization of content materials in teacher education have been explored. Today philosophizing is increasingly supported by research data in picturing the function and preparation of the teacher who has competence.

Historical Trends in Teacher Preparation

Van De Voort (33) discussed the history of the preparation of science teachers in normal schools and teachers colleges in four periods. The period 1832-1860 emphasized discipline of mental faculties and object teaching; 1860-1910 was characterized by departmentalized science and the introduction of special-methods courses; 1910-1920 emphasized organization on basic principles, functional science of the environment, and general education courses as a supplement to special-methods courses. In the interval from 1920 to the present there has been a growing movement for professionalized treatment of subjectmatter. These findings were supported by Glover's study (14) of biological courses offered in midwestern teachers colleges. Lecture method with museum demonstration flourished until about 1880. After the early emphasis on taxonomy, the aspects of morphology and physiology gained headway. Under the influence of Agassiz and Huxley, laboratory and "type" study of biological specimens developed about 1900. Reaction against the type study appeared about 1920, and unified biology courses stressing principles and processes slowly appeared. Now there is an increasing tendency to provide a "science" major or minor, and survey courses. Glover presented evidence that teachers colleges, in copying the liberal arts curriculum, became degree-granting institutions with lack of clarity in aim. Studies which attempt to clarify the function of the teacher-preparing institution and the preparation which the teacher needs for his job are of significance at the present time.

Teacher Opinion as a Criterion for Training Programs

Several studies have reported teachers' opinions about their responsibilities, the adequacy of their teaching, and, directly or indirectly, the

adequacy of their preparation. Witherspoon (36) analyzed experiences of a sample of teachers graduated from California state colleges in 1939 and 1940. The teachers believed science experiences should be part of the elementary program, yet only 6 percent of the teachers believed they dealt adequately with science. Their avoidance of it was due to lack of personal knowledge and preparation and inadequate training with simple equipment. They reported courses in nature study as of greatest value, and broad integrated courses as particularly important. Teachers were in favor of professionalized courses in science which would work with curriculum materials and methods of presenting science, especially physical science, to children. Brechbill (5), using questionnaire responses, found high-school science teachers of the opinion that courses in the teaching of science were of more value than other courses in education.

Hagen and Samuelson (16) reported for the Committee on Subject Matter Preparation of the North Central Association. Questionnaire responses from mathematics teachers in twenty states indicated the importance of a training program that includes: a broad general education; intense training in mathematics; training in closely related minors of physics, general science, and chemistry; and general and special courses in professional education. More than 90 percent of the teachers favored a general education background including sciences, social sciences, art, music, literature, religion, philosophy, and ethics.

Burnett (6) reported a study which formed a research basis for the report of the Subcommittee on Teacher Education of the National Committee on Science Teaching. Data secured from elementary- and secondary-school science teachers throughout the United States corroborated findings of Witherspoon and Hagen. A majority of the respondents (generally more than 80 percent) conceived their major function to be that of bringing their specialized abilities to bear on the problems and interests of young people. Teacher avoidance of a number of important problems of youth was said to be due in a large part to insufficient knowledge of the science issues involved. The author of the study concluded that subjectmatter courses organized originally for research workers, doctors, and engineers should be reorganized into functional courses for teachers. This conclusion was in harmony with the recommendation of the Committee on Subject Matter Preparation of Secondary School Teachers (24) that reforms in subject-matter preparation should be based upon a realistic understanding of the high school and its problems.

Teacher Information and Misinformation as Criteria

Taylor (31) reported that test scores of prospective elementary teachers entering a midwestern state teachers college were deficient in arithmetic mechanics and understanding. His comparison of the 1929 offerings of 187 normal schools and teachers colleges in 42 states with the 1935 offerings of 128 institutions in 39 states showed a decrease in number of semes-

ter-hours offered in arithmetic. Taylor recommended that the four-year course for prospective teachers should contain not less than eight semester-hours of professionalized mathematics, mainly arithmetic. Ralya and Ralya (26) made similar recommendations on the basis of their study of the science misconceptions of women who were prospective elementary teachers.

Teacher Activities as Criteria

An analysis (15) of the community relationships of more than 9,000 public-school teachers selected as a national sample showed the extent to which teachers are a part of the communities in which they teach. Greenhoe, having studied the teacher responses to a 50-item checklist, found that most teachers brought up in small towns teach in communities of the same size. More than 70 percent of the teachers and more than 50 percent of the administrators reported no community-betterment services; yet 95 percent of the teachers reported membership in one or more community organizations, such as the church, parent-teacher association, Sunday school, Red Cross, and so forth. One-third of the teachers reported no visiting at the homes of their students. Such data certainly have implications for the preparation of teachers.

Powers (25) reviewed literature bearing on the teacher's job and institutional practices (as of 1932). He suggested a broad program for the prospective secondary-school teacher including an orientation course in natural science; specialization in one or more sciences; general psychology and education; and substantial preparation in English and social studies. Seven years later Noll (23) presented a similar analysis and recommendations. In 1926, Finley (11) likewise recommended a broad preparation in biology, with induction into the other sciences; specialization in some science of interest; and professional courses such as those in methods and in curriculum.

Science Curriculum Materials as Criteria

Rudy (29) analyzed 84 elementary science textbooks and 38 courses of study and recommended for the preparation of elementary science teachers (a) a functional course in physical science and one in biological science related to the needs and interests of elementary students; (b) an introductory course in one special science field, emphasizing methods of science; and (c) a final course stressing methods of presentation and curriculum construction. Billig (3) derived content for a professional course in science for elementary-school teachers by an analysis of literature and of outlines of science curriculums in elementary schools. Technics of teaching prospective teachers included illustrative demonstrations, experiments, readings, field work, and the use of visual aids suitable for students in elementary grades.

Benner (2) analyzed the topics in general science textbooks and courses of study to determine the percent of content from each of the special science fields. This pattern of text content she compared with the actual science preparation, and with the state certification requirements, of teachers of general science. Lack of preparation was especially evident in the fields of agriculture, astronomy, bacteriology, geology, and meteorology—fields from which more than 25 percent of general science topics are drawn. Certification requirements for general science in most states were found to be those for any specialized branch of science.

Present Status of Preparation of Teachers

Boone and Jameson (4) found that about 13 percent of 855 science teachers in California junior and senior high schools had no college training relevant to subjects they taught. The percent of adequately trained teachers in 1934 was estimated to be not in excess of 40. Douglass and Stroud (10) reported a similar study of 1,024 secondary-school science teachers in Minnesota. The majority of the teachers having one or more classes in science did not have a college major in science. Especially in the small schools in the state it seemed difficult to obtain teachers qualified to teach several fields of science. Wright (37) examined catalogs of 255 institutions of higher learning which trained elementary-school teachers. One-fourth of these required a unit in high-school science for admission. Four institutions required six courses in science during training; at the other extreme, five institutions required no science training of prospective elementary teachers. Two-thirds of the institutions required three or more courses in some science; biology was most often mentioned specifically. The state requirements for certification of elementary-school teachers were found to be generally lower than were the training school requirements, both in total length of the training period and with respect to the number of science courses demanded.

Ford (12) analyzed the catalogs of 36 teachers colleges in the area served by the North Central Association to determine minimum requirements for prospective science teachers. He found that only four colleges required work in earth science and astronomy and that four colleges limited their requirements for a science major to beginning courses in science. Ford's conclusion was that few of the colleges studied required enough work in the entire science field to prepare for teaching the sciences offered in high school. Hicks (17) examined the preparation of science teachers in Texas to determine the extent to which they had met the state requirements. Of the beginning teachers in 1934-1935, approximately one-half had elected nonscience majors in college. However, 82 percent of all science teachers in the state had met the state requirement, and the number of adequately prepared teachers was apparently increasing.

Sneltz (30), of the American Committee of the International Commission in the Teaching of Mathematics, found that secondary-school teachers

of mathematics had units of college credit in mathematics ranging from 0 to 90 semester-hours, with 20 percent of the teachers having less than 20 semester-hours. Most mathematics teachers taught in additional fields, especially science and social studies. Turner (32), in the Fourteenth Yearbook of the National Council of Teachers of Mathematics, contrasted education of mathematics teachers in the United States with that in England and Wales. In the United States, teaching requirements are generally determined by certification agencies, with minimum requirements averaging between 15 and 18 points in mathematics—an amount insufficient for competence, according to Turner. Academic qualifications were found less high in America than in England and Wales. The study pointed out that academic and education departments differed in points of view. The education department considered that knowledge of the problems of children and of society constitutes a focus toward which subjectmatter competence should be directed; academic departments stressed logical organization of subjectmatter. American teachers colleges were thought to evidence an increasing professionalization of subjectmatter.

Gemmill (13) investigated the amount of science for prospective elementary science teachers in 16 institutions in 10 states. In about half of the cases, students were graduated with only one science course, usually biology. Exclusive of 17 percent of the group who had taken general science, only 5 percent had had any work in physical science. In many instances, students were able to graduate without studying any science. Davis (9) reported that one-fourth of the Ohio elementary teachers were securing eight hours or less of science, and that one-half were securing twelve hours or less. On the basis of a review of literature, Davis recommended that science teachers in the elementary school have some contact with the philosophy of science education. Rhodes (28) compared the records of elementary teachers in a California county in 1928 and 1938, and found a 42 percent increase in quarter units of science during the ten-year interval. He noted an increase in introductory professionalized science courses.

Cunningham (8) analyzed curriculums and facilities in use in 17 teachers colleges and in 25 elementary schools and found need for further equipment for teaching physical science teachers. Crosby (7) found that the critic teacher in science was selected on the basis of teaching success, scholarship, personality, years of experience, and science preparation.

Professionalized and Survey Courses in Science

Although studies have recommended professionalization of subjectmatter, the nature of desirable professionalization has elicited only a limited amount of research. Hurd presented a series of studies (18, 19, 20, 21) designed to determine what constitutes professionalized subjectmatter in practice. He reported (a) the viewpoint of instructors in science in institutions preparing teachers, (b) student reactions to professionalized courses,

(c) descriptive accounts by instructors of professionalized courses. Although Hurd found that institutions preparing elementary-science teachers were in advance of other institutions, he said: ". . . we cannot hope that a science curriculum composed largely of conventional courses designed for no one in particular unless it may be the prospective biologist, physicist, or chemist, will meet the needs of prospective teachers of elementary, junior high, or senior high pupils." According to Baker (1), teachers of professionalized and integrated courses indicated that they were offering courses from the viewpoint of science as a way of living and of meeting problems of life, were attempting to balance biological and physical science content, and were building content around general principles or areas of living. Watson (35) found that instructors in physical science survey courses in high school and junior college have been prepared to teach separate physical sciences rather than a generalized course. Watkins (34) studied patterns of sciences offered in Missouri high schools and identified a need for teaching majors in science rather than majors in some branch of science. Reynolds (27) found a 76 percent increase in teachers colleges offering a complete pattern of generalized science rather than a single course during the interval of 1934-1938.

In-Service Education

Mathewson (22) secured teacher judgment on needs for in-service education and on ways of meeting these needs. The most common needs were: "making science more functional, providing adjustments and applications to life," and "skill in organizing the content and methods of science to achieve the aims and objectives." Others were evaluation of other than factual assimilation; provision for diversified pupil activity; broad understanding of the aims of science education as a part of general education; and understanding of child and adolescent psychology, drives, and interests. The most common suggestions for meeting these needs were science educational books and magazines, and campus or extension courses. Others were science books, research and curriculum revision by committees of science teachers, programs of science teachers associations, and general educational books and magazines.

Needed Research

Research studies of the past twelve years dealing with the preparation of science and mathematics teachers have been primarily concerned with broad outlines and sequences of courses. Rarely has research considered the science and professional content which would be of optimum value to teachers. This circumstance was to be expected in view of the transition during the past decade from a subjectmatter to a general-education emphasis. Detailed research into content and methodology would have been rather sterile with the function of the teacher in presentday America so

unclear. Now precise studies of functional courses designed to meet the needs of prospective teachers would be in order. Research of the past decade has pointed toward functional science courses to prepare teachers for dealing with problems of young people and society. It is to be hoped that research of the next decade will clarify the nature and relative values of various functional materials in science teaching.

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